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MENTAL AND PHYSICAL DEVELOPMENT

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AMERICAN EDUCATIONAL RESEARCH ASSOCIATION

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Volume III **April, 1933** **Number 2**

Mental and Physical Development

(Literature reviewed to November, 1932)

Prepared by the Committee on Mental and Physical Development: Fowler D. Brooks, Psyche Cattell, Harold E. Jones, and George D. Stoddard, *Chairman;* with the assistance of Dorothy E. Bradbury and Helen L. Dawson.

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FOREWORD

We may not believe in the child centered school—I, for one, do not—but this in no way prevents us from recognizing the necessity of a thoroughgoing knowledge of the nature and development of the child and the youth. While the nature of education is not solely determined by the psychology of the individual child, both the ends and the methods of education must be adapted to the child's nature at every point. Education bristles with problems which require a knowledge of mental and physical growth for their solution.

Some of this knowledge we do not yet possess. That it is accumulating at a tremendous pace is attested by the body of literature which is reviewed in this number. Those who have not followed this literature have, perhaps, thought of the study of childhood and youth as having ended with G. Stanley Hall. It is true that Hall and his coworkers did do an enormous amount of work. The studies of this school, however, are seldom relied on for current generalizations, perhaps not as much as they should be. Their eclipse is shown by the fact that Hall's name appears only seven times in *The Handbook of Child Psychology*, published by Clark University. In contrast, seven other authors are mentioned over twenty times each. The literature which is mentioned in the current summaries is for the most part recent, and consists largely in reports of studies using more exact technics than were used by the earlier workers in the field. These facts make the summaries of peculiar importance.

FRANK N. FREEMAN,
Chairman of the Editorial Board.

INTRODUCTION

It became apparent very soon to members of this committee that they were delving into fields extensively explored by a variety of scientific workers: anatomists, anthropologists, biologists, pediatricians, psychologists, statisticians, and educationalists. Hence one criterion of selection was taken to be the significance of the research for students of education. In this way it was possible to omit practically all the publication of physicians and clinicians and a great mass of duplicative "measurement" projects in psychology and education.

This issue is based primarily on publications since 1925, earlier studies being included if they are still research currency in their respective fields.

George D. Stoddard, *Chairman,*
Committee on Mental and Physical Development.

CHAPTER I

Mental Development from Birth to Puberty

1. INTRODUCTION

IT is obvious, as a matter of common sense and observation, that the mental growth of the normal child proceeds as he advances in years. Yet the difficulties obstructing the study of mental growth are many. The measuring instruments are not sufficiently accurate to record small differences in mental growth, and we have no satisfactory units of measurement and no zero point on our scales. The intelligence tests have offered invaluable assistance in determining the quantity and type of education which will be of most value to an individual child or to a group, and in narrowing the fields of endeavor toward which the pupil should be guided in the selection of his life work. The concepts of mental age and intelligence quotients have served to aid the schoolman in the interpretation of intelligence test scores. But when it comes to the scientific study of growth, the intelligence tests with their mental ages and I. Q.'s fall short.

Mental age units are not satisfactory for use in the study of mental growth. By definition, the average amount of growth which takes place within one year is equal to one mental year, whether between the ages of four and five or between twelve and thirteen; though it is generally conceded by psychologists that the annual increment of mental growth becomes smaller as maturity is neared. Many psychologists hold that this process of slowing up in the rate of mental growth invalidates the I. Q. In an attempt to overcome this and other weaknesses inherent in the I. Q., a number of substitutes have been proposed such as the "Personal Constant" of Heinis (53), the "Absolute Scale" of Thurstone (103, 105, 106), the "Isochrons" of Courtis (21), the "Index of Brightness" of Otis (80, 81), and the better known sigma indices or standard scores. These measures, however, also have their weaknesses, and a large majority of the studies of mental growth are still being expressed in terms of mental ages and I. Q.'s with a smaller number in terms of raw scores or sigma indices.

Only a limited number of studies professing to deal with mental growth use repeated measurements on the same child. The majority compare the mental achievement of a group of ten-year-olds, for instance, with the achievement of a group of eleven-year-olds made up of entirely different individuals. Even when the results of measurements repeated annually on the same individuals are averaged year by year, the resulting figures are not satisfactory. This can best be made clear by an example taken from the field of anthropometric measurements. The so-called adolescent spurt of growth in height is well-known. It has been proved by Davenport (26) and others that this period of accelerated growth does not commence in

all children at the same age. In girls the usual time falls between the ages of eleven and fourteen. Some girls aged thirteen years will be in the midst of the rapid growth period, while others will not have entered it, and still others will have passed beyond it. To take the average increment and say that it is typical for thirteen-year-old girls is misleading. A postadolescent girl should be expected to have a much smaller increment of growth than one who is passing through the period of most rapid growth. Mental growth is no doubt characterized by similar, but subtler complications.

Mental growth curves based on different intelligence tests at varied age levels are of doubtful value unless the tests have been equated, for the age norms of the tests vary with the population on which the tests have been standardized. This has been shown by the work of Ratcliff (86), Kefauver (66), Cole (18), Steckel (96), Cattell and Gaudet (16), and others. Even tests that give identical mean I. Q.'s for a given group of unselected children may give very different results at one or both extremes. In comparing the differences between the Binet I. Q. and those obtained from eight group intelligence tests, Cattell (13) found (to take extreme instances) one test in which the median of the differences (signs considered) between the group test I. Q. and the Stanford-Binet I. Q. was only 1 point in a group of children with Binet I. Q.'s near 100. In those with Stanford-Binet I. Q.'s above 129, the median difference was -12 and of those below 80, $+7$. Even two forms of the same test standardized under the direction of the same author may give widely different results at the extremes of the distribution of intelligence. For children with Stanford-Binet I. Q.'s of 130 and higher, one form of one test was found to give median I. Q.'s approximately 9 points lower than the median Binet I. Q.'s. The other form given to the same pupils one year later rated them approximately 16 points higher than the Stanford-Binet. Carroll and Hollingworth (12) have demonstrated that children with Stanford-Binet I. Q.'s between 133 and 190 averaged 17 points lower on the Herring-Binet. Again, as Woodrow (118) pointed out, a child may make a good showing in one type of test and a poor showing in another. Goodenough (43), using the Kuhlmann Revision of the Binet Scale, reported a correlation of .81 between test and retest at an interval of six weeks for preschool children. Updegraff (107) showed that for preschool children reliability is increased by postponing testing until two weeks after entrance to school.

It is not intended that this discussion shall reflect upon the fine work that has been done in the construction of intelligence tests. When the facts are known, the above mentioned weaknesses in the tests are not insurmountable difficulties to their use in child placement and guidance in school or elsewhere. But they render an adequate study of mental growth wellnigh impossible.

The difficulty is not avoided by repeating the same test year after year. It has been shown by Ratcliff (86), Snedden (94), Cattell and Gaudet

(16), and others that when a child is given the same test which he has taken previously, even after an interval as long as a year, he usually gains an appreciable amount in I. Q. According to Snedden (94) this gain is not due to a real acceleration in mental growth or even, in any large measure, to familiarity with the general test situation. He found only a slight gain when an entirely new test was administered after a period of one week. Cattell and Gaudet (16) also found that children who had increased their I. Q.'s through repeating a test at an interval of one year dropped back to their former level when a new test was introduced.

In addition to the difficulties encountered in the lack of a zero point, a satisfactory unit, and reliable measuring instruments, there is the problem of determining when there is an increase in real ability, and when an increase in score is due to the acquisition of some specific information. If there is a real increase in mental ability, it is a question whether it is innate or due to environmental influences.

A number of studies have been excluded from this review because the factors of selection or test standardization are mixed with the factor of growth. An example of this is the study of Banker (5) who, obtaining his material from the literature, plotted a mental growth curve from the first grade of the elementary school through the university. As excellent as this study may be for the determination of the average mental age of pupils in the various grades, it does not throw light on the rate of mental growth because the extent to which the yearly increase in mental age is due to the falling away of the duller pupils is unknown. Another example is a study by Sanchez (90) who gave Haggerty Intelligence Tests to a group of Spanish-speaking children of New Mexico four times within sixteen months. He found an average I. Q. gain of approximately 20 points. This increment may have been in part an artifact resulting from the effects of practice, differences in the standardization of the two tests used, or increase in ability to use and understand the English language.

In spite of all the restrictions mentioned above, it is clear that differences in performance on existing standardized tests and procedures have some bearing on the question of child development. Although the perfected units, tests, growth curves, and rigid definitions do not exist, it will be profitable to examine critically representative studies.

2. MENTAL DEVELOPMENT IN INFANCY

The most detailed and extensive experimental work on the mental development of infants in the last five years is that of Arnold Gesell and his associates at the Yale University Clinic (36, 37, 38, 39, 40, 42). The study was based on detailed examinations including stenographic and cinema records. In many cases the same individual was examined seven, eight, or more times at intervals of a month or longer. From these records, a series of test items was constructed for each of the first ten months after

birth and also for twelve, fifteen, eighteen, twenty-one, twenty-four, and thirty months of age. An earlier book by Gesell (40) gave a similar series for thirty-six, forty-eight, and sixty months. A number of test situations were selected which were appropriate for use at different developmental levels. For example, a small sugar pellet 5 mm. in diameter is placed in front of the child. The typical infant gives it transient visual regard at five months, attempts to secure it with raking movements at six months, but does not succeed until seven months. At eight months he plucks the pellet with partial predominance of ulnar digit, and at nine months "picks pellet with opposite thumb and index finger, approximating finger prehension."

In a number of subnormal, average, superior, and atypical mental growth curves presented and described by Gesell (36), evenness of growth was found to be the rule. Cases of atypical growth were small in number and stood out as relatively exceptional. After reviewing the results of tests made on subnormal infants, he reached the conclusion that mild degrees of retardation bordering on the lower level of normality can be detected at nine months or earlier, and that pronounced cases of mental deficiency can be diagnosed soon after birth whether or not they are accompanied by physical signs. Bühler and Hetzer (8), on the other hand, wrote that "intellectual disorders" could not be recognized before the end of the first year except in-so-far as backwardness was a matter of "very low learning ability." In such a case it could be detected in the middle of the first year. At both the clinics of Bühler and Gesell it has been found more difficult to diagnose superior mental development than mental retardation.

Bühler and her coworkers (7) developed a series of tests for each month of the first year after birth and for every three months of the second year. Preliminary to the selection of test items, the investigators observed a number of infants under one year of age continuously for twenty-four hour periods during both waking and sleeping. Every bit of observable behavior was recorded. The infants were observed in their normal environment, 40 percent in private homes, and 60 percent from the Kinderübernahmsstelle. It would seem that these children from the institute might be subnormal, although Bühler did not believe this to be the case. From these extended and detailed observations, the experimenters constructed tables giving the changes in the proportion of time spent by the infant in different types of behavior as his development increased. Table 1 will serve as an example.

The authors then compared a group of children from a favorable environment with another from an unfavorable environment. During the first four months they found no appreciable differences in development. At five months the favored children showed an advance over the nonfavored, and by one year the difference had increased to one month.

In a study of 277 infants under one year of age tested with the Linfert-Hierholzer Infant Scale (68), Furfey (33) quoted correlation coefficients

TABLE 1.—PERCENT OF TIME SPENT BY THE INFANT IN DIFFERENT TYPES OF BEHAVIOR.

Reactions[1]	Age (Months)				
	Birth	3	6	9	12
Sleep and dozing	88.7	76.8	56.1	57.5	55.0
Negative reaction	7.0	12.0	8.4	7.3	6.4
Positive reaction	3.3	8.2	8.5	7.7	7.6
Spontaneous reaction	1.0	11.0	27.0	28.0	31.0
Total	100.0	100.0	100.0	100.0	100.0

[1] Other classifications, such as condition of comfort, receptive waking, and quiet displeasure, were also given.

between intelligence rating and the Chipman-Sims Home Rating varying from +.31 to —.24 for the different age groups to support the conclusion that in the case of infants aged one year or less there is no significant correlation between intelligence of offspring and parental status in the socio-economic world. Four years later Furfey and Muehlenbein (34) retested seventy-one of the same children with the Stanford-Binet Test. The correlation between the Stanford-Binet I. Q.'s and those obtained from the infant scale was .00 ± .07. The authors correlated the change in I. Q. between the Linfert-Hierholzer and Binet Tests with the Chipman-Sims Home Rating made at the time the infants were tested and obtained a coefficient of .33. They inferred from this that the lack of correlation between two tests may have been due, in part, to the fact that at the time of the infant tests the environment had had only a short time in which to exert its influence.

Bühler and Hetzer (7, 8) held that low developmental quotients could be brought up to normal through appropriate training, except when such traits as memory and ability to imitate were almost entirely lacking. They cited several cases in support of their contention. On the other hand, Gesell reached the conclusion that the development of the nervous system would proceed to its optimum development even in the presence of severe handicap, and that special training would have no effect on the final level of mental development. Evidence on this point was given by Gesell and Thompson (37). One child of a pair of infant identical twins was trained in certain behavior while the other was held as a control. The twins were very similar in physical appearance, anthropometric measurements, and developmental history. Beginning at the age of forty-six weeks Twin T was given twenty minutes of daily, systematic training in stair climbing and playing with cubes. At the end of six weeks' training Twin T could readily climb the stairs without assistance; the control Twin C could not

climb them even with assistance. Twin C was then given five minutes of training each day for two weeks. By the end of one week she could climb without assistance and before the end of the second week was quite as proficient as her sister. No difference could be observed between the response of the trained and untrained twin in regard to cube play.

Gesell (36) cited cases of premature and postmature babies showing that the developmental trend was the same as that of a full-term infant when the prematurely born infant's chronological age was calculated from the date of expected birth. Mohr and Bartelme (72) compared the development of 113 prematurely born infants with forty of their siblings and found no significant differences in the development of the two groups. The great majority of the prematurely born succeeded in performances of the Gesell Tests suitable for the age when corrected for the degree of prematurity. The authors found, however, a greater variability among the premature infants. Comberg (19) also found the mental development of prematurely born children, aged three to seven years with birth weights under 2,500 grams, to compare well with full-term young children.

Capper (11), in a less objective and less well-controlled study, came to the opposite conclusion. He studied as one group 437 children with birth weights under 2,500 grams, 276 being classified as premature, two postmature, and the remainder full-term. He found that as a group they were markedly retarded in physical development and still more so in mental development. There are several possible explanations of the conflict between the results of this study and those reported above. Perhaps the two most important are the fact that the author included full-term immature infants with the prematurely born, and that his subjects were hospital patients, many of whom admittedly had had serious and chronic diseases.

By means of parents' testimony, Smith (93) attempted to determine the effect of illness on the development of such traits as sitting, creeping, first words, and spoken phrases. It was found that when illness preceded the development of a given trait, the infant showed a retardation of about 12 percent over those who became ill after the development of the traits. The experiment, however, does not appear to have been well-controlled. Aside from the unreliability of the method of collecting the data, no record was given of age at the time of illness.

McGraw (70) examined with the Hetzer and Wolf Baby Tests an unselected group of infants consisting of 50 percent of the negro and 50 percent of the white babies born in a certain community during one year. Sixty negroes and sixty-eight white infants were tested. No evidence was found that negro babies mature earlier than white babies.

Careful and detailed observations of the development of the infant during the first ten days after birth were made by Weiss (109) and by Pratt, Nelson, and Sun (85). The conclusion drawn was that the reactions of

the older infants were similar to those of the newborn in kind but differed in precision and speed.

3. MENTAL DEVELOPMENT OF THE PRESCHOOL CHILD

The study of the mental development of the preschool child has been beset with many difficulties. Many child psychologists have tended to discount the value of mental tests in the study of young children because of the unreliability of the results obtained.

Hallowell's study (50) would indicate, however, that the results at these levels are more reliable than was at first believed. The subjects of the study by Hallowell were 436 children who varied in age at the time of the first test from three months to forty-seven months. Each child was given from two to eight tests at intervals ranging from six months to seven years. Fifty-two and five tenths percent of the cases varied less than 5 points when the initial and final diagnosis was made, 79 percent varied less than 10 points, 17.8 percent varied from 10 to 19 points, while only 2.3 percent fluctuated more than 20 points. Where there was a change in diagnosis, about twice as many improved as deteriorated. Children from thirty-six to forty-seven months varied less on retests than did children from three to thirty-six months.

Stutsman (97) standardized a series of mental tests for children from two to five years of age. The final norms represent a total of 631 cases, 300 boys and 331 girls. For three groups of children, feeble-minded, average, and above average, correlations with the Stanford-Binet Test were $.79 \pm .05$, $.79 \pm .02$, and $.78 \pm .03$, respectively.

A number of investigators have been interested in the effect of an enriched environment on the mental growth of the preschool child. Gesell and Lord (41) selected eleven pairs of children between the ages of thirty-one and fifty-two months matched for age and time spent in nursery school. One of each pair was taken from a nursery school in a very poor district, the other from a nursery school located in a superior district. A clinical examination showed that the children from the favored homes were superior to those from the poor districts in virtually every field with the exception of self-help which includes such behavior as washing, fastening buttons, and putting on shoes. There the "unfavored" children excelled.

Studies made by Hildreth (54) and by Goodenough (46) indicated that nursery-school training had little if any effect on mental growth. Twenty-eight children who had had one year of nursery-school training were tested with the Kuhlmann-Binet five weeks before entering the first grade, one week after entering, and again at the end of the first school year. A control group was obtained by carefully matching in all important respects each child of the nursery-school group with a non-nursery-school child. Goodenough (46) found that both groups gained in I. Q. during the year. She attributed this gain to imperfections in the standardization

of the test. The gain of the nursery-school pupils was slightly larger than that of the control group, but not by a sufficient amount to take the difference outside the limits of chance. A coefficient of correlation between days of attendance in nursery school and I. Q. gave no indication of an acceleration of mental growth due to school attendance. Hildreth (54) found that forty-one children who had received four months or more of nursery-school training had, on entering the first grade, an I. Q. 6 points higher than a control group who had had no previous training. But after a period of training in the first grade, the second test showed that the group that had had no previous training gained 4 points in I. Q. while the average I. Q. of the previously trained group remained stationary. If the initial difference in I. Q. of the two groups was caused by the early school training of one, it proved to be only a temporary advantage.

The results of a study made by Barrett and Koch (6) are in conflict with those given above. They found that a group of twenty-seven orphanage children who attended nursery school for six or nine months showed a distinct acceleration in mental development, as measured by the Merrill-Palmer Tests, over a control group in the orphanage not attending school. The nursery-school group gained 21 I. Q. points during a period of from six to nine months. During the same period of time the control group gained only 5 points. Wellman (110, 111) also found a marked increase in the I. Q. during the school year for kindergarten and nursery-school children. She attributed the gain to an acceleration of mental growth caused by the training received in school. A slight general rise in the mental growth curve during the school year with a corresponding drop during the vacation months was found by Jordan (65). Wellman's data show a stationary I. Q. during the summer months.

4. MENTAL DEVELOPMENT OF THE SCHOOL CHILD

A pioneer study in the field of mental growth was that of Baldwin and Stecher (4). Individual records of the 143 children examined (five to fourteen years of age) were divided into four groups: (1) fifty-six cases having two examinations, (2) fifty-one additional records having three examinations, (3) forty-two of the preceding group on whom a fourth examination was obtained, and (4) additional thirty-six having five consecutive examinations. From the mental growth curves resulting from this study, it was apparent that superior and average children develop at different levels, and that children of these different intellectual levels grow increasingly dissimilar in mental age with increase in chronological age. An analysis of the curve revealed a significant change in trend with the approach of adolescence, which appeared earlier in the case of superior children. There was also "an adolescent superiority of girls which is in accordance with other facts indicative of the earlier maturity of girls" (4: 22).

Jordan (65) tested a group of pupils at six semi-annual intervals. The tests used varied according to the grade in which the pupils were located. His results indicated that mental growth approaches a straight line with a slope close to 45 degrees. The bright and the dull pupils showed the same absolute amount of gain in terms of mental months as did the average. Growth curves for those pupils who took the first test at each of five different ages run almost parallel, even though superimposed according to the number of tests and not according to age. All showed a decided tendency to flatten out after the fourth testing, at which time the youngest group was only ten years of age and the oldest fourteen. No explanation of this finding was offered.

From tests repeated at annual intervals for six years, Hirsch (56) concluded that mental growth at all levels of intelligence was such that the I. Q. remained constant. For the different levels of intelligence this would give mental age curves which diverge in contrast to those running parallel as reported by Jordan (65). Cattell (14) and Wheeler (113) also obtained results leading to the conclusion that the mental age growth curves of the bright and of the dull child tend to diverge from the norm with increase in age.

Freeman (32) presented growth curves from repeated tests in sentence completion, vocabulary, analogies, and opposites. His data led him to the conclusion that different abilities develop at different rates (32: 41):

> For example, the rate of growth in *sentence completion* is more rapid from eleven to thirteen than it is from eight to eleven. The rate decreases rather sharply at age fifteen. In *vocabulary*, on the other hand, the rate of growth is most rapid in the early years and decreases gradually throughout the period with no sudden break. In *analogies* the rate of growth is fairly constant up to fourteen, if we disregard the variation in the first year, and then falls off rather sharply. In *opposites* the curve is rather similar to that in *vocabulary*, except at the two extremes where it resembles more closely the curves in *analogies*.

Variability also was found to differ for these skills. A marked difference in the changes of the standard deviation with age was also noted in the different functions. The units of this study were raw scores; hence it is possible that part of the changes noted were the result of inequality of units.

Hirsch (55) and Wheeler (112) studied the intelligence of mountain children of Kentucky and Tennessee respectively. Both reported a marked decrease in intelligence quotients with age. They differed, however, in interpretation of the results found. Hirsch found a steady drop from 85 at the seven-year level to 73 at thirteen. After thirteen there was a slight gain probably due to the dropping out of the duller pupils. Wheeler's cases showed a steady drop from 95 at six years of age to 74 at sixteen on the Dearborn Tests, and from 85 at eight years to 69 at sixteen years on the Illinois Tests. From an analysis of his data, Hirsch reached the conclusion that probably about one-fourth of the difference between the

I. Q.'s of these Kentucky mountaineers and the norm could be accounted for by environmental factors, and the remainder by heredity. Wheeler believed that "the mountain children are not as far below the normal as the tests seem to indicate. With the proper environmental changes the mountain children might test near a normal group." However, in a previous study of a group of city children with average I. Q.'s below 90, Wheeler (113) stated that the dull children were retarded 11.7 months at age six, and that the retardation increased each year until at the age of ten they were 29.3 mental months retarded. This indicated an I. Q. drop of from 84 to 76.

Thurstone's method of scaling has been used in the study of mental growth by several authors. Thurstone and Ackerson (105) applied the scale to 4,208 Stanford-Binet mental ages obtained at the Institute for Juvenile Research at Chicago. All grades of intelligence were included but a disproportionate number were retarded, the average I. Q. being about 80. The mental growth curves were found to be positively accelerated up to the general level of ten years, the inflection point falling between nine and twelve years—earlier for the bright than for the dull child. The several age groups were not composed of the same children and the group as a whole was a selected one. It is possible that the selection of cases may have influenced the trend of the curves.

William (114) used Thurstone's methods of scaling on data from the Goodenough drawing test (44). She found a definite negative acceleration in the rate of growth with age, and noted also that children of different levels of intelligence (as determined by acceleration or retardation in school) progress along parallel lines. Both of these conclusions are in conflict with those of Thurstone and Ackerson. William offered as a possible explanation of these differences the fact that the test which she used was of the performance type. In other words, these investigators may not have been measuring the same ability.

Odom (79) also used Thurstone's method of scaling in plotting the growth curves for four well-known group intelligence tests. He concluded that the growth curve is generally negatively accelerated, but that it is sometimes slightly positively accelerated and occasionally is a straight line.

This review includes the growth curves for six different tests scaled and presented by three different authors. Among them mental growth is plotted as a straight line, positively accelerated, and negatively accelerated. It is possible that mental growth is so complex that the different tests measure entirely different functions, and that some of these different functions are negatively accelerated with age in contrast to others which show positive acceleration. It is also possible that there may be something wrong with the tests or with the method of scaling.

5. THE MENTAL GROWTH OF THE INTELLECTUALLY INFERIOR AND THE INTELLECTUALLY SUPERIOR CHILD

Chipman (17) and Jewell (60) divided the mental growth of the feeble-minded into types. Chipman's 1,751 subjects, inmates of the Fernald State School, fell into two groups: (1) "those that show a spurious evidence of rapid development during their early years but gradually become relatively more and more retarded;" and (2) "that type which shows a long-continued but very slow rate of growth over a greater number of years than is common." Jewell (60), after an analytical study of fifty borderline cases at the Vineland Training School, found one type of growth curve in which the I. Q. tended to increase, another in which it tended to decrease, a third in which it remained constant although fluctuating, and a fourth, constant without fluctuations. The first question which arises in regard to these statements is: Are these distinct types of mental growth curves or merely examples taken from the extremes of a more or less normal distribution of variations in mental growth?

Cunningham (23) compared the mental attainments of a group of idiots and imbeciles with a group of normal children of the same mental ages. At the two-year level he could find nothing which would clearly differentiate between the performance of the two groups in Thorndike's CAVD Test, but from this age up to the four-year mental level the normal children gained on the idiots, at which level both groups made the same score. From the mental ages of four to six the imbeciles gained on the normal children, until at the six-year level they obtained a score 18 points higher than the normal children.

There has been much disagreement among psychologists as to what proportion of the feeble-minded in our institutions and elsewhere is the result of heredity and what proportion is due to other causes. It is, however, generally agreed that the children of the feeble-minded have small chance of developing a superior mentality, though in most instances the child's mental development is superior to that of his feeble-minded parents.

Martz (71) studied the mental development of the children of a group of twenty-five delinquent girls with an average I. Q. of 54. The children showed average physical development, but none was above average in mental ability, and 60 percent had defective mentality. Yet with one exception every child showed a mental development superior to his mother's. The author interpreted these results as indicating the recessive character of mental deficiency. In a similar study of a group of twenty-five children of borderline feeble-minded delinquent mothers, Atkinson (2) found that in only two cases was the intelligence level of the child below that of its mother. In ten it was above, and in the remaining thirteen, approximately on the same level. Since in neither of these studies is the mentality of the father known, it cannot be determined whether the superiority of the child's mentality over that of the mother was due to inheritance from the

father, to a general tendency to regress toward the mean, or to the possible recessive characteristic of feeble-mindedness as Martz suggested.

Similarly it has been found that parents from the higher socio-economic levels (hence of higher intelligence on the average) produce a larger proportion of children of superior mental development than any other group. From a study of three hundred cases aged eighteen to fifty-four months, Goodenough (45, 48) found that the mean Kuhlmann-Binet I. Q. of the children showed a consistent and fairly regular decrease as the scale of occupational classes descended. The data showed that intellectual differences between social classes are well established by the ages of two, three, and four years. The difference between the classes was no greater at the ages of three and four than at two years.

Russell (89), in a study of superior rural children, found that approximately 50 percent of the selected group came from homes high in the socio-economic scale. Among other studies which indicate a positive relationship between socio-economic status of the parents and the I. Q. of the children may be mentioned those of Burks, Jensen, and Terman (9), Bühler (7), Sirkin (92), Furfey and Muehlenbein (34), and Freeman and others (31). When studying the effects of a rural environment on ability to pass the several items of the Stanford-Binet, Jones, Conrad, and Blanchard (61) found their group of 351 rural children averaged 10 points below the norm and estimated that 5 points were probably due to environmental factors. They stated that "the handicap is specific in the sense that it is greater for some tests than for others; in some tests it appears to be absent entirely, and probably in no test is it adequate to account for the entire difference between rural and urban children." Armstrong (1), in reviewing the literature on the relative intelligence of rural and urban children, reached the conclusion that the intelligence of rural children was from six to twelve months behind that of urban children. From her own data, she concluded that this difference disappeared when parental status was equated. Baldwin, Fillmore, and Hadley (3) reported the results of mental tests on 678 rural-school children ranging in age from two to six years. When compared with 346 city children, the farm children compared favorably with city children on performance tests. They were consistently inferior on the tests of the Stanford-Binet which involved language or visual imagery.

The most extensive and important study of the mental growth of children of superior mental ability is that of Terman and his colleagues (9, 102) at Stanford University. In 1921-22, 1,000 children with I. Q.'s of 140 or higher were given intelligence tests and other types of examinations. As many as possible were retested six years later. The seventy-three cases who were under thirteen years of age at the time of the follow-up study were given a Stanford-Binet examination, the others the Terman Group Tests of Mental Ability. Both boys and girls lost in Stanford-Binet I. Q. during the six years; the loss of the boys was small, being 3 I. Q. points,

but that of the girls was 13 I. Q. points. The fluctuations in I. Q. found in Terman's group were appreciably greater than is ordinarily found in unselected groups. While most of the pupils still remained far above the average, one girl dropped to 100 and one boy and four girls dropped to below 120. Although there were no very pronounced sex differences in I. Q. change, the authors (9) reported that when direction of change was disregarded, decreases in I. Q. were greater for girls and gains greater for boys. Boys were more likely to have and retain high I. Q.'s. Changes in ability found over a term of years in a group such as was studied are concluded to be due "chiefly to change-of-rate factors inherent in the individual, and . . . are correlated with sex."

That the large decreases in I. Q.'s were probably not due to inaccurate selection in the first instance is shown by the fact that the cultural environment of the "lowered I. Q." group was as high as in the other group. Also the twenty-two siblings of the "lowered I. Q." group had an average I. Q. of 126, and the 179 siblings of the other cases had an average I. Q. of 120. Those children who were retested with the Terman Group Test of Mental Ability are of little help in the study of mental growth as no mental age norms were available, and there was little increase in score over that made six years earlier. Probably these superior pupils came too near "hitting the ceiling" in the first test to have much room for improvement in the second. The authors (9), however, concluded that taking the evidence as a whole there seemed to be reason for believing that the large sample of gifted children tested in 1928 on the Terman Group Test resembles fairly closely, with respect to distribution of mental ability, the small group retested upon the Stanford-Binet.

Cattell (14, 15) obtained different results using the data from the Harvard growth study. Her data pointed toward the conclusion that there was a definite tendency for pupils of low intelligence to decrease slightly in I. Q. as they became older, but that the bright showed an increase. Fifty-three cases with I. Q.'s below 80 lost, as a group, approximately 5 I. Q. points during a period covering from three to six years; while the forty-eight cases with I. Q.'s of 120 and higher gained approximately 8 I. Q. points during the same period. The explanation of the different results of the two studies is not clear. The two greatest differences in the materials studied is that the Stanford group was of a much higher grade of intelligence and that the cases were selected on the basis of the initial I. Q., while those from Harvard growth study were classified on the basis of the mean of two or more Stanford-Binet I. Q.'s. The two studies do agree in the direction of sex difference. In the one the girls lost more I. Q. points than the boys, while in the other the boys gained more than the girls.

Nemzek (74) retested a group of fifty-two gifted children aged seven to nine years inclusive with the Herring-Binet Examination after an interval of one year. He found more gains than losses. The middle 50 percent

of the changes in I. Q. ranged from —2.8 to +12.3. Since there was only one year between the two examinations, perhaps it is more likely that the excess of gains over losses was due to practice rather than to an accelerated rate of growth. Cox (22) cited a large number of incidents showing that many geniuses gave evidence of unusual ability as children. She stated that the extraordinary genius who achieves the highest eminence is also the gifted individual whom intelligence tests may discover in childhood but that the converse of this proposition is yet to be proved.

6. NATURE, NURTURE, AND MENTAL GROWTH [1]

The influence which general environment and special training exert on the rate and final level of mental development is a subject of perennial interest and controversy. The two most important studies in the field are probably those of Burks (10) and of Freeman and others (31). Both these studies used foster children for their subjects. Burks limited her work to children who had been placed in their foster homes before their first birthday and who had been legally adopted. The ages of the children ranged from five to fourteen years at the time of the investigation. Both the true and the foster parents were of non-Jewish, North European extraction. An intelligence test was given to at least one of the foster parents in 204 cases. Burks found a correlation of .19 ± .05 between foster mother and child and one of .05 ± .05 between foster father and child. In a carefully matched control group the correlations between true mother and child and true father and child were .46 ± .05 and .45 ± .05 respectively. The I. Q. of the foster children correlated to the extent of .25 ± .05 with a cultural index, while in the control group the correlation was .44 ± .05.

A summary of the conclusions reached by Burks is given below:

1. Home environment contributes about 17 percent of the variance in I. Q.; parental intelligence alone accounts for about 31 percent.
2. The total contribution of heredity is probably 75 or 80 percent.
3. Measurable environment one standard deviation above or below the mean of the population does not shift the I. Q. by more than 6 or 9 points above or below the value it would have had under normal environmental conditions. In other words, nearly 70 percent of school children have an actual I. Q. within 6 to 9 points of that represented by their innate intelligence.
4. The maximum contribution of the best home environment to intelligence is apparently about 20 I. Q. points, or less, and almost surely lies between 10 and 30 points, conversely the least cultured, least stimulating kind of American home environment may depress the I. Q. as much as 20 I. Q. points. But situations as extreme as either of these probably occur only once or twice in a thousand times in American communities.

Freeman and his colleagues (31) had a less homogeneous group to work with. Therefore, they divided their cases into several groups. Some of their more important results are:

[1] In order to avoid duplications, many studies pertinent to the understanding of the influences of nature and nurture upon development, which have been included under "The Mental Development of the Preschool Child" and other headings, have not been included in this division.

1. A group tested before and several years after placement showed significant improvement. The correlation between I. Q. and foster home rating was .34 ± .07 before placement and .52 ± .06 after about four years.

2. The correlation between forty pairs of own-child foster-child was .34 ± .09; when home rating was rendered constant, .15 ± .10. Seventy-two pairs of unrelated foster siblings in the same home correlated .37 ± .07. Burks (9) found a coefficient of .23 ± .14 between foster siblings living together.

3. The correlation between foster child I. Q. and home rating in 401 cases was .48 ± .03; between an Otis intelligence rating of foster father and Binet I. Q. of foster child the correlation was .37 ± .04; and between foster child and foster mother, .28 ± .04.

4. A group of siblings was divided into two groups by placing in one group the member of each pair who was in the better foster home and in the other the one who was in the poorer home. The mean I. Q. of the group in the poorer homes was 86 while that of those in the better homes was 95. The correlation between the I. Q.'s of the siblings reared apart since the age of five was .25 instead of the usual .50. "When the comparison was made for those whose foster homes were of different grade, the correlation was found to be only .19. These facts make it appear that a part of the resemblance between siblings reared together is due to the influence of a similar environment."

The authors were of the opinion that the selection of superior homes for the superior child did not take place to any large extent, since they found that the intelligence of the child was not usually taken into account as a major consideration of adoption.

The findings of these two major investigations are in general agreement, though the Chicago study would indicate that the environment is more potent in affecting the rate of mental growth as measured by the intelligence tests than does the Stanford study. However, the interpretations of the significance of the findings differ markedly. In the Chicago study the importance of the differences found was emphasized, while the author of the Stanford study held that the influences of the environment on mental growth were not large enough to be of much practical importance.

Teagarden (101) cited the case of two children aged eleven and eight years who were first tested when living under conditions which it would be difficult to make any worse as regards social and physical features. Several years later they were tested again when living under ideal social and physical conditions. A marked improvement in moral, physical, and domestic habits and skills had taken place, but "the I. Q.'s obtained for each child remained unusually stable despite the change of environment, the average deviation for Grace being 1.68 and for Lulu 1.92." The author concluded that the obtained I. Q.'s were a function of native intelligence much more than of environment. The original I. Q.'s were 73 and 77 for Grace and Lulu respectively.

Rogers, Durling, and McBride (88), in a study of sixty-four girls who were transferred from extremely poor social and educational conditions "to exceedingly good and well-managed institutions," did not find improvement during the first year. The correlation coefficient as found by Denworth (28) between number of days of school attendance since first entering school and Binet mental age for 700 pupils was +.20 ± .02. Be-

tween Stanford Achievement educational age and number of days of school attendance the correlation was .30 ± .02. He concluded that the differences in the number of days spent in school had but little effect on mental development or on educational acquirements. On the other hand Bühler and Hetzer (8) cited examples to show the importance of environmental factors in the mental development of infants, while Gesell and Thompson (37) were entirely unsuccessful in their attempts to increase the intelligence rating of one of a pair of identical twins by special training.

Twins and siblings have been used by several investigators in an attempt to untangle the relative importance of heredity and environment in determining the rate and height of mental growth. In such studies the assumption is usually made that both the environment and heredity of monozygotic twins are practically identical, that fraternal twins and siblings have a similar environment but somewhat different heredity, and finally that unrelated children living in different homes have a totally different heredity and environment. The fact that these assumptions have been made too blithely is pointed out by Jones and Wilson (64).

Perhaps the most striking of these studies is a series by Newman (75, 76, 77, 78) on identical twins reared apart since infancy. To the extent that the assumptions above are correct any differences in mental development existing between two members of a pair of identical twins can be attributed to environment. Newman studied four pairs reared apart and compared the differences in mental test score made by each pair with the average of differences found in fifty pairs of identical twins and fifty pairs of fraternal twins reared together. The two members of both Case I and Case II differed from each other in Binet I. Q. by twenty-three mental months or nearly three times as much as the average of fifty pairs of identical twins reared together. Only five of the fifty control cases varied as greatly. In both cases these differences were corroborated by the results of group tests. It is noted in regard to Case I that the two girls showed a much greater similarity in their physical and emotional makeup than they showed on the intellectual side. In regard to Case II Newman says, "In contrast with the great difference in mental power stands the fact that in all the tests of emotional traits and of temperament the twins give the impression of being remarkably and unusually similar."

The two members of Case IV showed even greater difference in mental ability, their Stanford-Binet I. Q.'s being 106 and 88. This difference of 18 points was 3.3 times greater than the average differences between fifty pairs of identical twins reared together and nearly twice as great as that between fifty pairs of fraternal twins reared together. In some of the emotional tests strong resemblances were noted, while others revealed notable differences. Both twins in Case III obtained Stanford-Binet I. Q.'s within two points of each other. The group test I. Q.'s differed a little more but not to any great extent. These twins, from homes of similar culture and economic status where they had received a very similar type and amount of formal educa-

tion, were "nearly identical" in intellectual ability but "utterly different" in personality. To these four cases may be added a similar study made earlier by Muller (73) on a pair of identical twin girls reared apart. He found both members of the pair to be very similar in all physical, mental, and emotional traits tested.

In summary, the results show that two of the five pairs of identical twins reared apart were very similar as regards mental development and markedly different in personality, while two other pairs differed considerably in mental ability but had strikingly similar personalities. The two members of the fifth pair were strikingly different both in intellectual ability and in personality makeup. Of the four pairs of twins studied by Newman, the average differences in I.·Q. between the two members was 10.9 points or 20.7 months of mental age; while the average differences for the control group of identical twins reared together were 5.3 and 8.4 respectively, and for the group of fraternal twins 9.9 and 15.9 respectively. Thus the fraternal twins reared together were found to be more alike on the average than the four pairs of identical twins reared apart. Obviously no definite generalization can be drawn from so few data with such wide variation in results. Newman inclined to the opinion that heredity is twice as important as environment. He stated that "perhaps the most disconcerting fact revealed by the data is that fraternal twins reared together are on the average about one and a half times more similar in mental rating, as judged by intelligence tests, than are identical twins reared apart." But he goes on to say that undoubtedly the intelligence tests test more accurately the effects of training than of native endowment. "The same is probably true of the temperament-emotional tests, in that they measure the effects of emotional experience rather than native temperament, if there is such a thing." Newman observed that if the environment were more powerful than heredity, identical twins reared together should not be twice as similar as fraternal twins reared together.

Holzinger (58) devised mathematical formulae to study the relative effect of nature and nurture on fifty-two fraternal and fifty identical twins and concluded that the two were about equally important in producing mean twin differences in intelligence. He found some evidence that the differences were greater for the older than for the younger twins, also that nurture was more effective for the younger than for the older. He then concluded that nurture influences played an important part in determining mental development, and that they were the cause of about one-half of the differences found between twins. Hirsch (57) concluded from a study of a group of similar and a group of dissimilar twins, some of whom had spent part of their lives in different homes, that heredity was about five times as important as the environment in determining mental growth. But his conclusions are weakened by the fact that he used traits which may have been influenced already by environment as a basis of classification into similar and dissimilar pairs. From a study of 158 pairs of twins and 199 other

siblings, Tallman (100) obtained the following Stanford-Binet I. Q. differences:

Siblings (separated by less than four years)	13.1 ± .71
Twins	7.1 ± .26
Siblings (separated by less than two years)	12.0 ± .96
Unlike-sex twins	8.5 ± .52
Like-sex twins	6.4 ± .30
Probably identical twins	5.1 ± .47
Probably not identical twins	7.4 ± .61

Tallman concluded that (1) twins are twice as much alike as are other siblings, as measured by I. Q. ratings; (2) the results obtained from a group of unlike-sex twins resemble those obtained from siblings more closely than they do other twin groups; and (3) like-sex twins who have similar appearance resemble one another in intelligence more closely than those who look distinctly different. Wingfield (115) presented the following table of correlation coefficients between pairs of children of different degrees of blood relationship:

Physically identical twins	.90
Like-sex twins	.82
Fraternal twins	.70
Unlike-sex twins	.59
Siblings	.50
Parent-child	.30
Cousins	.27
Grandparent-child	.15
Orphans	.00
Unrelated	.00

Reviewing the results of the accompanying table Wingfield concluded that the closer the genetic relationship between individuals, the closer the degree with which they resemble each other in general intelligence. "Ergo, intelligence is an inherited trait"; or we may add, ergo, effective environment is more nearly similar for twins than for siblings.

The correlation between intelligence test scores of pairs of siblings has been found to be in the neighborhood of 50. Since this is the same as has been found for physical traits which are believed to be unaffected by environment, it has sometimes been assumed that the degree of similarity represented by a correlation coefficient of 50 represents the amount of similarity due to heredity.

Sims (91) compared the correlation coefficients between the intelligence of pairs of siblings from the same home with unrelated children living in different homes. The author used the Otis Test as a measure of intelligence, and the Sims Score Card to determine the socio-economic status of the home. Each pair of the unrelated group consisted of one of the siblings matched for age, school attended, and social background with some other child outside the sibling group. The intelligence test scores of 203 pairs of siblings

correlated to the extent of .44 ± .04 or .40 ± .04, depending on whether the single or double entry method was used; the correlation between the 203 pairs of unselected schoolmates was .35 ± .04 and .28 ± .04 respectively. Sims says that a "common environment produced a correlation of .35 or .29 depending on the method used, while the addition of common parentage raised the correlation to .44 or .40, again depending upon the method used. . . . The indications are that intelligence, so far as we are today able to measure it, is greatly influenced by environment." We cannot, however, be sure that the correlation between the unrelated pairs is not due to inheritance from parents of like ability rather than to like environment.

Jones (62) found the correlation between child and mother to be about 5 points higher than between child and father. Burks (10) found the correlation was 1 point higher, but between foster-mother and foster-child it was 12 points higher than between foster-father and foster-child. Goodenough (47) found a correlation 6 points higher between the child's I. Q. and mother's education than between the father's education and the child's I. Q. indicating that the child resembles the mother slightly more than the father. However, Freeman and others (31) found a correlation 9 points higher between foster-child and foster-father than between foster-mother and foster-child.

Wingfield and Sandiford (116) and Wingfield (115, 117) studied the intellectual resemblances between 102 pairs of twins from public schools and twenty-nine orphanage children. The orphanage children who had been brought up together in an orphanage (similar environment) for a considerable length of time were no more alike in intelligence as shown by correlation coefficients than children in general paired at random, and no difference in the amount of correlation was found between younger and older twins (living longer in same environment). In view of these findings the authors concluded that the resemblance of the twins could not be due to environment. Also as regards siblings living in orphanages and unrelated children in the same environment, Davis (27) found no greater resemblances among them than among those in the public schools, and he concluded that heredity is the all important factor in determining the rate of mental growth.

But it is open to question whether twins and siblings should become more alike as they grow older on account of long-extended sharing of a similar environment. It seems more probable that the environment of two children in the same family becomes increasingly different as they grow older and have had more opportunity to develop individual interests and friends. During the first nine months of life a pair of twins would seem to have a truly identical environment, provided they are equally favorably placed in the uterus. When the mother takes care of both twins and both are in equal health, the first year is probably very similar. But it frequently happens that one twin is weaker than the other, thus requiring more attention,

or that the main part of the care of one twin is delegated to a "mother's helper." Therefore, it appears that if the environment is an important factor in determining mental growth, twins and siblings should be more alike at birth than at any later period of life. The argument that orphanage children should be more alike than children in general if nurture is important in determining mental growth is also open to question, especially when the method of study hinges on the correlation coefficient. It is probable that the orphanage children are a select group in the first place. If their similar environment had tended to bring children nearer together intellectually, it would decrease the range of differences for the whole group which would tend to lower rather than raise the correlation coefficient. Moreover, similar environment, while often referred to, is never adequately analyzed to show the extent of similarity for each child.

The results of these studies on the influence of environment on mental growth are too conflicting to attempt any general conclusion. All that can be said is that the authors of the majority of the more important studies concede that a favorable environment probably has some effect on intelligence as measured by our intelligence tests, and that very few investigators would attribute to environment more than one-half of the differences in mental ability ordinarily found among children. Most investigators put the proportion considerably lower.

Even if all the studies were beyond criticism (which they are not) and if all agreed that nurture was an important element in determining the I. Q. (which they do not), we would still know but little regarding the effect of nurture on mental growth. We have no way of determining whether a given environment which has had a favorable effect on the I. Q. caused a real acceleration in the development of general mental ability, or whether it has merely placed the child in a favorable position for obtaining certain superficial bits of information and skills which were of help to him in making correct responses to the specific items of the usual intelligence tests.

7. ORDINAL POSITION AMONG SIBLINGS AND INTELLIGENCE

A number of studies on the relationship between ordinal position among siblings and intelligence have appeared in the last few years. Commins (20) and McFadden (69) both found that the earlier-born children made a better showing on the intelligence tests than the later-born. In these studies, however, the size of the families was not controlled, and it has been shown by a number of studies, such as those of Lentz (67) and Guilford and Worcester (49), that it is the parents with the lower grades of intelligence that have the larger families. Thus there is an undue number of children of unintelligent parents among the higher ordinal numbers.

Thurstone and Jenkins (104) in order to avoid this pitfall, compared the first-born with the second-born children from the same families, the second-born with the third-born, the first-born with the third-born, etc. The complicating factor of extra-familial social and economic status was thus

equated. This study includes comparisons of sibling pairs in families of from two to eight, including in all about eighteen hundred comparisons. Not only were the first-born lower in intelligence than the later-born, but the second-born were lower than the third, the third lower than the fourth, etc. In all groups where the number of cases was large the trend was consistent, the difference in I. Q. between the first and the eighth born being 17 points. There is, however, the possibility that the results were influenced by the fact that the subjects consisted of those who had been tested at the Institute for Juvenile Research in Chicago. They included a wide range of intelligence levels, the I. Q.'s varying from 0 to 140, with the mean in the neighborhood of 80.

Steckel (95), in a well-planned study including 5,928 pairs of siblings in which social status and size of family were controlled, also found the later-born children to be superior to the earlier-born. She found a consistent and appreciable increase in intelligence with increase in ordinal number from the first through the eighth-born child.

Sutherland (98) used as subjects only the children of men working in mines without distinguishing position of any kind. In this way he roughly equated the socio-economic status of his group. The average I. Q. of the children was 99.9 with a correlation of $-.04 \pm .02$ between chronological age and I. Q. The correlation coefficient between I. Q. and size of family was $-.12$. The median I. Q. for the different sizes of families and the median size of family for different intelligence levels both point to a slight but fairly consistent negative relationship between number of siblings and intelligence. Later Sutherland (99) studied two groups of children, one containing 123 children who had been fatherless since birth and another group containing 724 children who had been fatherless for a shorter period. This method of selection was used for the purpose of controlling voluntary limitation of families. The group that was fatherless from birth decreased irregularly in I. Q. from 101 to 80 as the size of the family increased from one to seven. A control group matched for siblings and age decreased from 107 to 94. The group of 724 fatherless children decreased in I. Q. from 99 to 91 with size of family. This study is unconvincing because of the small number of families of each size and because, as the author points out, it is not known to what extent births were controlled before the death of the father.

Jones and Hsiao (63) studied the relative intelligence of the older and younger of 330 pairs of adjacent siblings and 284 non-adjacent pairs in an unselected sample from isolated New England communities. Contrary to the results of the studies cited above these authors found a mean difference of only $-.01$ of a standard deviation between the younger and older adjacent siblings and a difference of $-.06$ between younger and older non-adjacent siblings. They concluded that birth order yielded no significant difference in central tendency for the population in question. The same conclusions were reached by Hsiao (59) in a later study of 2,127 first- and

second-born siblings. The conclusions based on intelligence tests were supported by the grade placement of the children studied.

8. INTELLIGENCE AND AGE OF PARENTS

Steckel (95) found the intelligence of the child to increase steadily with the age of the mother up to twenty-six years of age and of the father up to the age of about thirty. After these ages the I. Q. of the child declined. She found the first-born at all parental ages appreciably and consistently above the average of children in general, but the size of the families was not controlled and the author was of the opinion that the explanation of the results lay in socio-economic factors rather than in biological factors. A third conclusion reached, for which Steckel offered no explanation, was that children with parents near the same age had higher I. Q.'s than those with parents whose ages differed widely, and that the greater the difference the lower the I. Q. of the child, especially when the mother was the older. Finch (30), using the average of five equated group test I. Q.'s, found no correlation between the age of either the mother or the father and the I. Q. of the child.

9. MENTAL GROWTH AND RACE

Psychologists have been unable to prove whether or not there are racial differences in intelligence to say nothing of racial differences in the process of mental growth. In addition to the complications encountered in the study of growth within a national group are those involved in the study of racial differences in general. Estabrooks (29) pointed out the weaknesses in the usual technic used for studying race differences in intelligence, weaknesses which have led most psychologists and anthropologists to look upon their results and conclusions with suspicion. This was obviously due to the fact that the critics questioned the ability to measure the intelligence of any group of people with tests devised to gauge that of another group. Moreover these different groups, even after they have been tested, are not always treated from a racial standpoint. There has merely been a testing of a cultural group which may or may not be racially homogeneous.

In the case of the Japanese, for instance, it might be racially homogeneous but probably would not. In the case of the Jew or Italian, there is even greater uncertainty. Race depends on physical characteristics only.

In the face of so many complicating factors, it does not seem worthwhile to do more than mention a few studies comparing the mental growth of negroes and whites. Davenport (24, 25) studied a group of negroes, whites, and browns in rural Jamaica. He found the negroes superior to the whites in some of the sense discrimination tests and the whites superior in tests where organization, foresight, planning, logic, and common sense were involved. The browns ranked between the two. Since the blacks and browns lived side by side in rural Jamaica, the author concluded that dif-

ference in environment could not account for the difference in intelligence and that it must, therefore, be racial. In this study, however, as in others there is no proof that the samples were typical. If there had been either a selection in the direction of superiority among the Germans who migrated to Jamaica four generations before or if the negroes on the island were inferior to negroes in general, the scores of the browns would probably lie between those of the whites and blacks without necessarily indicating a general racial difference.

Peterson and Lanier (82) showed the whites to be superior to the negroes in the same school systems of the South in a number of intelligence tests, but since the negroes and whites were in different schools there is no guarantee that their educational opportunities were equal. Garth, Lovelady, and Smith (35) found the mental growth of negroes to be at practically the same point as the whites in the fourth grade, but from then on the blacks lagged further and further behind the whites with increase in age. The authors were of the opinion that the lag began too early for social stress to be a factor. McGraw (70) found an appreciable difference in the mental development of negroes and whites under one year of age.

Following a review of some thirty-five studies, Viteles (108) concluded that negroes were consistently inferior to whites on practically all tests of mental ability. Although in every instance there was considerable overlapping between the two races, the negro scores taken as a group contained a consistently higher proportion of inferior scores and a smaller proportion of superior scores than did those of the whites. There was evidence that the amount of difference between groups increased with age. Many of the investigators, however, did not consider the evidence scientifically valid. According to Viteles it would be possible for anyone interested in the problem of negro-white differences to choose from among these varied conclusions one which best suited his particular bias.

10. THE DEAF AND THE BLIND

Pintner and Paterson (83) and Reamer (87) have compared deaf and hearing children on non-language group tests. In both of these investigations the deaf fell decidedly below the hearing child. With about one thousand cases on the digit-symbol and symbol-digit tests, Pintner and Paterson (83) reported the percentage of deaf boys reaching or exceeding the median for hearing boys as 24 and 31 percent respectively; for deaf girls as compared with hearing girls, 10 percent for both tests. They concluded that the deaf child was about three years behind the hearing on these two tests. Reamer (87), using a more comprehensive non-language test with about twenty-five hundred children, found the deaf about two years behind the hearing at all ages where representative groups of deaf and hearing children were compared. Pintner (84) found no difference between the intelligence of those born deaf and those who became deaf after birth.

In general, blind children seem to be inferior to sighted children on comparable intelligence tests. Hayes (52) compared 670 blind children tested by means of the Irwin-Binet Tests and one thousand unselected children as tested by Terman. Pupils above average in intelligence were much less common among the blind than among the sighted. The number of feeble-minded blind was particularly large. He also reported that the average attainment of 122 blind subjects on the Pressey Group Tests was considerably lower than the average for the sighted. In another study, Hayes (51) found the median I. Q. of the blind about 10 points below that of the sighted.

CHAPTER II

Mental and Physical Development in Adolescence

THE more valuable general bibliographies and abstracts covering mental and physical development are discussed in other chapters and are not referred to here. The literature on the effect of nature and nurture upon physical and mental development until puberty has been reviewed and evaluated in the other chapters. Since little further need be said on it for the period of adolescence, it is not reviewed here. The general plan will be to treat the more significant researches of the past eight years, with exceptions in the case of earlier important ones whose comparison with later studies seemed advisable. The discussion is confined almost exclusively to studies reported in the United States, England, and other English speaking countries.

The value of data depends very much upon the methods by which they are secured. Some important considerations in methodology on problems of development during adolescence relate to (a) selection of subjects, (b) environmental changes, (c) measuring instruments used, (d) retests or non-retests, and (e) statistical and other technics.

Since environmental factors may affect development in some differential fashion, the selection of subjects may vitiate results. Likewise, significant changes in environment may alter the course of development. The use of valid, reliable instruments of measurement is a *sine qua non* for satisfactory educational research. Precision in measuring physical traits is equally important and is strongly emphasized in recent work. Data from anthropometric measurements taken in physical education departments are often very inaccurate. Standing height measurements taken in one university physical education department showed many women students taller (with shoes removed) as beginning freshmen than they were one year later as beginning sophomores!

Retest vs. non-retest method—Data secured by retesting individuals at successive ages are generally preferable to measurements of many different individuals of each of the various ages. Such data enable us to plot individual growth curves. The non-retest method yields only a generalized sort of curve which, however, has considerable theoretical value. If care is taken to ascertain whether any significant changes in environment have taken place, the value of the retest method is enhanced. Either method necessitates adequate analysis and study of possible factors so that cases may be properly selected or the specific conditions described. Certainly with respect to adolescent development, cases selected at random do not necessarily constitute a random sample as in card sorting, nor does ignorance of the kind of sample drawn make it random. Lack of funds, difficulties in securing suitable subjects, as well as faulty insight into the problems

themselves and the technics appropriate to their solution often limit the quality of researches on development. In this discussion all retest studies are indicated.

1. MENTAL DEVELOPMENT IN ADOLESCENCE

Research materials on mental development during adolescence are treated under seven headings:

1. Age of cessation of mental development; the mental age of adults
2. Rate of mental growth; the mental growth curve during adolescence
3. Constancy of the I. Q.
4. Range of individual differences in intelligence
5. Sex differences in mental development
6. Effect of pubescence upon mental development
7. Miscellaneous topics

Age of Cessation of Mental Development

The subject of this chapter presupposes some mental development during adolescence. Following the World War and the widespread use of mental tests, an extensive literature appeared which was interpreted as showing that the mental ability or "native" intelligence of the average white man in the United States was approximately thirteen years, and that mental growth, therefore, ceased about the age of thirteen or fourteen years. If mental growth ceases by the beginning of puberty, no reason exists for discussing the other problems listed, unless deteriorations during adolescence disturb the *status quo ante.*

But researches reported since 1925 agree with the retest data reported between 1921 and 1924 in placing the age of cessation of mental growth above thirteen or fourteen. Ballard (131) gave data on this problem for English children, and Cobb (153) reported data on several thousand children in the United States.

Retest studies, 1921-24—Stanford-Binet retest studies by Baldwin and Stecher (4) on normal and superior children showed mental growth continuing until chronological age sixteen, the highest age tested. Brooks (144), retesting with an extensive battery of tests, found mental growth continuing until age fifteen, the highest age tested, but at a rate indicating no immediate cessation. Johnson (198), retesting 422 high-school pupils with a group test after one year, found mental growth continuing until eighteen, the highest age tested.

Kuhlmann (200) retested 639 feeble-minded individuals every two years for ten years with the Kuhlmann-Binet and found mental age increasing until around fifteen for idiots, fifteen or sixteen for imbeciles, about seventeen for morons, and about eighteen for borderline cases. While the exact amount of mental growth cannot be ascertained directly from mental ages on age scales like the Binet and its revisions, an increase in mental age from one year to the next probably represents an increment in intelligence. Thurstone and Ackerson (105) held that "the mental growth curve for

bright children approaches the level of test-maturity sooner than that of dull children." Freeman (169), Brooks (146), and Thorndike (240) also give data on this point.

In all the foregoing studies no attempt was made to determine and eliminate practice effect, so that the actual gains were somewhat less than those reported. Thorndike (240), after estimating and subtracting practice effect in Brooks's data, found his results still holding. Thorndike (241) retested 8,564 high-school pupils after one year, using the I. E. R. tests of selective and relational thinking. After allowing for practice effect, he found mental growth continuing until eighteen, the highest age tested. In all these studies the unit of measurement was mental age on a Binet revision, points of score on a group test, or standard measures (where scores from a variety of tests were combined).

Studies reported from 1924-32, the scale units those of the tests—Woolley (258) made an extensive study using annual retest of two groups of Cincinnati children ranging in age from fourteen to eighteen. One group included children who quit school at fourteen to go to work, and the other those who expected to remain in school. They numbered approximately fifteen hundred at the beginning and around seven hundred at the end. The tests used were essentially those used in a study reported in 1914: tapping, card sorting, cancellation, rote memory, substitution, and completion. Practice effect was not allowed for. The results indicated that "the easier the mental task, the earlier an approximate adult status is reached. Thus, in memory an adult status is attained for the seven-place series at fifteen, for the eight-place at sixteen, and for the nine-place at seventeen years." In substitution gains after sixteen were negligible. Development of the functions measured continued as long for the working children as for those in school, indicating that schooling was not the cause of the continued gains. The working group probably was not above the average of an unselected population of these ages, since less than half of them had reached the seventh grade at the age of fourteen (144:73).

Freeman (169) and Brooks (146) cited data from various group intelligence tests and other tests indicating, in-so-far as such data can, that mental growth continues until ages ranging from fourteen to eighteen. Freeman noted that discrepancies in results are due largely to differences in difficulty of the tests used or in selection of cases for study. Dearborn and Cattell (161) found the point scores and mental ages on the Dearborn Tests of several hundred private-school children, ages twelve to nineteen, greater at age eighteen than at any previous age. Hart (187) concluded from the results of the Army Alpha Test with several hundred part-time and full-time school children that mental growth gradually approaches a point of cessation at the age of sixteen or seventeen.

Pintner (84) gave data on deaf and hearing children, ages twelve to fifteen, which show both groups having higher scores on his non-language test at fifteen (the highest age reported) than at any age before, the in-

crease in mean scores being approximately the same from year to year. Sudweeks (236) used the Terman group test with eighteen hundred continuation-school pupils in Wisconsin and found scores increasing until age nineteen; too few cases were tested at this age to make the results reliable. In testing several hundred mentally gifted adolescents with his group test, Terman (9) found the scores higher at each successive age until nineteen. Woodrow (118) found no cessation in increase of test scores with age "at any rate up to 18.5 years," when he tested all the public-school children in a small town ($N = 1572$) on a group test.

Luh (209) found mental growth among Chinese children continuing until sixteen, the highest age he reports. Jordan's (65) six semi-annual retests of 183 children on National Intelligence Test, scales A and B, showed growth to fourteen, the highest age tested, but there was little indication of an early cessation thereafter. Thorndike (242), using a random selection of two-thirds of those retested in his earlier study (241), made allowance for practice effect and for selection and found mental growth continuing "beyond eighteen."

Use of "absolute" scales and scales in "truly equal units," 1925-32—Thurstone (106) determined the mental growth curve by applying two formulae (see next section) to the scores of three thousand London school children, ages three to fourteen, tested by Burt on his Binet revision. He concluded that "it may be that this curve, if continued, would drop its acceleration to reach a limit in the early twenties, or perhaps even at the age of twenty, but it can hardly be extended to reach a limit much sooner than that." Thurstone and Ackerson (105) applied Thurstone's method of scaling to the Stanford-Binet mental ages of four thousand white children three to seventeen years old who were examined at the Institute for Juvenile Research at Chicago (mean I. Q. about 80). They plotted a mental growth curve which "tentatively" shows mental growth continuing until age eighteen and beyond.

Odom (79) used Thurstone's method of scaling on group test data from several sources, involving nearly ninety thousand cases ranging in age from five to nineteen, and plotted seven mental growth curves which seem to indicate that mental growth continues until seventeen or even longer. Wright (259) applied Thurstone's method to data from nearly seven hundred students in the University of Pennsylvania, ages seventeen to twenty-two, on tests alleged to measure "fundamental abilities" (memory span for digits, syllables, and ideas; a number test; directed and undirected attention) and "complex mental processes" (Roback opposites, abstraction, reference, and judgment; Brotemarkle definition; and Trabue language scale J). From these data he reported evidence indicating a more rapid rise of the latter curve during these years, although the small number of cases at age twenty-two and the lack of definite information about selection at the various ages render the results highly tentative.

Thorndike and others (240) presented data from several sources scaled so that the scores are expressed in "truly equal units." These indicate that mental growth, measured by present tests of intelligence, continues "until eighteen or later." Using the South African Group Test of Intelligence (scaled according to Thorndike's method) on more than sixteen thousand school children of European descent in the Union of South Africa, Wilcocks (255) found mental growth continuing until sixteen, the highest age tested, with the slope of the curve indicating no immediate cessation of growth.

Inadequacy of tests to measure growth of intelligence during adolescence—Dearborn (162) criticized his own and other studies which seek to discover the mental age of adults from existing tests after referring to the work of Hopkins (194) and others upon which he concluded that the average adult age on the Dearborn Tests is about fourteen and one-half years. To him it appeared obvious that by using tests largely scholastic in nature it will be found that children's improvement in general intelligence (or general school learning) can be measured only as long as they stay in school. After leaving school "they may be improving their minds by learning something else or they may be stultifying them in some occupation which requires the acquisition of no new skills, but only the automatic employment of those they have; but whether there is, or is not further intellectual development, the tests are not competent to tell. . . . The tests do not discover all the intelligence of all the pupils, even when they are in school" (162: 305).

This view is shared by Thurstone (106), Thorndike (240), Freeman (169), Brooks (146), and others who discuss the nature of mental growth, especially during adolescence. It rejects the once strongly affirmed view that existing intelligence tests measure native intelligence until the age of fourteen or fifteen, and that thereafter growth ceases.

Mental age of adults—Since a given mental age usually means the average mental ability of an unselected population of that chronological age, the average mental age of adults, strictly speaking, should be the average chronological age at which mental growth ceases. Miles and Miles (212) have shown that from the high point in the intelligence score curve represented at about eighteen years of age the trend is at first almost level, then gradually declines, dropping fifteen or sixteen mental age months by the chronological age of fifty years. The average mental age of adult white population in the United States is not, according to data from the researches we have already presented, as high as eighteen years or more on the Stanford-Binet or other intelligence tests. From the data and discussions published by Freeman (169), Thorndike (240), Thurstone (106), Symonds (238), Brooks (146), Dearborn (162), and the National Society for the Study of Education (215) it appears that intelligence tests emphasize materials whose mastery is greatly facilitated by school learning and other special environmental factors; they do not have items of suitable

difficulty at the later ages; they are not in accord with the interests of the late teens and early twenties; and they are standardized upon selected groups. Accordingly, any reference to the average mental age of adults on some particular test does not imply that mental growth usually ceases at that chronological age or that the average adult has the mental ability of the thirteen- or fourteen-year-old child, because neither common sense observation nor the results of many carefully made researches warrant either conclusion. Thurstone (106: 443) stated:

> [The Binet scale] should be extended beyond the age of fourteen or sixteen by inserting tests on which older subjects succeed better than younger ones. It is difficult to find test questions of the ordinary type in which such differentiation is possible, but our inability to find them does not prove that the development of intelligence stops somewhere in the 'teens. Common sense judgment certainly favors the assumption that the average man of forty is more intelligent than the average boy of twenty, but so far we have not been able to measure that difference. Instead of acknowledging this limitation in our measurement methods, we have not infrequently attempted to juggle with the definition of intelligence to make it fit the measuring devices that are accessible.

Rate of Mental Growth during Adolescence

Retest studies, 1921-24—Baldwin and Stecher (4) and Kuhlmann (200) presented data from retests with revisions of the Binet Tests which cannot be regarded as showing the rate of mental growth because the size of the units used in the scales, a year of mental age, may vary from one chronological age to another. That is, a year of mental age from three to four is not necessarily the same as a year of mental age from thirteen to fourteen or from sixteen to seventeen.

From retests on 172 pupils eight to fifteen years old, Brooks (144) reported mental growth from twelve to fifteen as functions of the average of the S. D.'s of ages eleven to thirteen, showing a decreasing rate which Thorndike (240), after allowing for practice from taking the tests, estimated as in the proportions of about nineteen, eighteen, and sixteen. Johnson (198) found on group-test retests that yearly gains from twelve to eighteen, with no allowance for practice effect, were in the proportions of thirteen, sixteen, thirteen, fifteen, twelve, and nineteen. Woolley's retest data on several hundred children, reported by Brooks (144), showed the rate sharply decreasing after the fifteenth year.

Studies, 1925-32—The rate of mental growth cannot be told from Hildreth's (189) data, for she used the Stanford-Binet in her extensive retests. Jordan's (65) study involved six semi-annual retests with the National Intelligence Tests A and B up to age fourteen. Two units of growth are used, points of score and mental ages, but, as Jordan notes, the shape of the curve from twelve to fifteen really is unknown. Hirsch's (56) extensive retests involved very few adolescents. Freeman (32), in a first approach, showed the advantage of repeated testings over statistical populations in analyzing the results of tests.

Thorndike's (242) retest data on more than five thousand high-school students indicated gains as hardly less than 100, 95, 90, 85, 80, and 75 from ages thirteen to fourteen, fourteen to fifteen, and so on to eighteen to nineteen when allowance was made for practice and the greater ability of the older groups to gain (due to selection). Thorndike comments, "Nor could anyone really prove from the facts at hand any decrease in gain" (242: 75). Terman and others (9) found the gains in scores for one group on his group test at successive ages from thirteen to nineteen to be 10.4, 4.2, 3.3, 4.2, 0.1, and 6.5 points respectively. But, as they pointed out, the value of the steps between points around 190 and 200 as compared with 150, 160, or 170 is unknown. Since the maximum possible score is 220 points, "the amount of mental growth with age remains in doubt and may well be larger" than shown by the median scores.

The mental growth curve during adolescence—Many have taken Baldwin and Stecher's (4) curves to be "actual mental growth curves." Mental ages from age scales like the Stanford-Binet cannot be plotted directly against chronological age, because, as Freeman (169), Brooks (146), Thurstone and Ackerson (105), Jordan (65), and others have shown, the size of the units is unknown at various ages. Plotting curves by laying off equal units in the vertical (or mental age) scale merely assumes that the units are equal, that the difference between any two successive ages is equal to that between any other two. We cannot know directly from the test anything about the size of the units. Age levels do have value, as pointed out by Gesell (39).

Thurstone and Ackerson (105) and others have called attention to the fact that "gross scores are clearly out of the question as measures of mental growth, except in-so-far as a rank order may be called measurement" (105: 569), since the size of units at high, middle, and low portions of a scale are not necessarily equal. Three fundamental attempts made to solve this problem yield different curves.

Luh (209) referring to the "Chinese system of intelligence tests" reported that "the relation between age and score was from the very beginning determined to be logarithmic." By making the unit equal to one-tenth of the S. D. of the twelve and one-half year group and arbitrarily giving a score of 50 to the average of that group (i. e., placing zero 5 S. D. below the mean of twelve and one-half-year-olds) the equation of mental growth was determined to be roughly: $\text{Score} = 79 \log (\text{Age} - 4) - 23.5$.

Luh gave the sigma distances between half years according to the Chinese formula to age sixteen, sigma increments from twelve to sixteen being .41, .37, .34, and .30 respectively. The curve for his data at the earlier ages conformed more clearly to the logarithmic. The derivation of Luh's equation is not given, but he says "the data from the Chinese group tests agree to a remarkable extent with the averages of the Binet records from which the equation was derived" (209: 185). He repro-

duced data from Pintner and Toops on American children which yield a curve almost parallel to that for Chinese children.

Thorndike (240) proposed a method of scaling tests to give "truly equal units" by using the distributions of scores in grade (or other) populations and assuming the form of distribution of intelligence to be the probability distribution. Four very important steps are to find the permille of individuals in a grade whose scores lie next below successive points and transmute them into sigma distances from the mean, then to find the differences between these sigma values of successive points or scores. These differences are divided by whatever sigma value equals, on the average, 1 point on the original scores. Using several masses of test data, he found that growth from fourteen to eighteen decreases, the curve flattening very much by eighteen. "The general drift of these determinations is toward a parabolic curve" (240: 466).

Wilcocks (255) found mental growth increasing at a slightly decreasing rate, the curve being nearly a straight line when he used the South African Group Test (scaled according to Thorndike's method) on several thousand twelve- to sixteen-year-old children of European descent.

Thurstone (106) presented two fundamental formulae for "an absolute method of scaling tests" whereby the mean ability of an age group may be established on an absolute scale when the mean ability of an adjacent lower age group is known. Thurstone took the lowest group of his data and put its mean at 0 and its sigma at 1. The two equations are (1)

$$\sigma_n = \left(\frac{S_{n-1}}{S_n}\right)\sigma_{n-1} \text{ and (2) } M = \sigma_{n-1}\left[(m-1) - \frac{S_{n-1}}{S_n}m\right] + M - 1$$

in which σ_n is the S. D. on the absolute scale of the age group in question, σ_{n-1} is the S. D. of the next lower age group (already known or assumed), S_n is the S. D. of the sigma difficulties of the test items for a particular year, and S_{n-1} is the S. D. of the sigma difficulties of test items for the next lower year. M is the mean on the absolute scale, $M-1$ is the corresponding mean of the next lower age, m is the mean of the sigma difficulties of the test items for a particular age, and $m - 1$ is the corresponding mean for the age next lower. Thus for each year the mean is expressed in terms of S. D. of the lowest age group with the mean of that group as origin.

The curve derived by this method from scaling Burt's data on three thousand London school children shows the rate of mental growth as rapid at fourteen as at nine. In another paper Thurstone and Ackerson (105) applied a similar method to scaling data on Stanford-Binet mental ages of 4,208 Chicago white children three to seventeen years of age. He used the mean test performance of four-year-old children as a tentative arbitrary origin and the S. D. of the seventeen-year-old group as a unit of measurement. Mean test performance was then calculated for each age. Absolute zero is defined by Thurstone (103) as the point where the variability becomes zero. By extrapolation it was located. The mental growth curve

plotted shows positive acceleration at earlier ages with an inflection point around the age of eleven and negative acceleration thereafter, but at fifteen or sixteen the curve seems to be rising with but slightly diminished speed. Thurstone (244) discussed this method of scaling tests.

Odom (79) scaled data from several group tests by Thurstone's method and plotted several growth curves, most of which were negatively accelerated with much flattening at the higher adolescent ages. Wright (259) also used Thurstone's method on data from college students eighteen to twenty-two years old and drew "theoretical" curves which are approximately straight lines with a steeper slope for "complex" mental processes than for "fundamental abilities." The data on which the former are based show a gain of 7.4 percent from eighteen to twenty-two, the latter a gain of .7 percent during the four years.

Thus three different shapes of curves are found—the logarithmic, the parabolic, and one resembling the ogive—which are taken by their authors to represent mental growth.

Constancy of the I. Q.

Not a great deal of work on the constancy of the I. Q. during adolescence has been reported during the last six years. Foran (168) prepared an excellent summary of studies reported to 1926 and Hildreth (189) a bibliography of thirty-four titles covering the years 1918-25.

Two ways of studying the problem have been employed: (a) finding the correlation between I. Q.'s on two or more testings, and (b) finding the median or mean differences in I. Q.'s or the *Q* of differences in I. Q.'s on test and retest. The former shows the relative ranks on tests and retests if chronological age is partialed out or eliminated by grouping to avoid spurious index correlation (239), but it tells nothing about the variation in I. Q. from one testing to another. To know the probable deviation of I. Q.'s on a second testing from those obtained on a first testing, actual calculation of the difference between test and retest I. Q.'s for each individual with suitable statistical treatment of these differences is the proper procedure. Usually the correlations between test and retest I. Q.'s are given, data from children of various ages being lumped together; more rarely they are calculated for each age group or the effect of chronological age is eliminated by the partial correlation technic.

Broom (147) used the Terman Group Test with fifty senior high-school students at an interval of six months to two years between first and second testing. The maximum difference in I. Q. was 13 points, the median approximately 5. Rugg (226) retested but one adolescent and Hirsch (56) a very few. Baldwin and Stecher (4, 123) and Hildreth (189) retested many adolescents with results similar to earlier Stanford-Binet retest studies. Garrison and Robinson (173) used the Stanford-Binet and the National Intelligence Tests on approximately two hundred children, ages twelve to fifteen, but the data are pooled with those for ages eight to

eleven. The data show a Q of approximately 3 points difference on the Stanford-Binet and 6 points on the National Test.

Terman and others (9) reported Stanford-Binet retest data on a few gifted adolescents, but the tests were inadequate for the retesting. Jordan's study (65) included the medians of group-test I. Q.'s on tests and retests, but the differences between these medians are not the median of an individual's differences between test and retest I. Q.'s. They show merely whether the I. Q. of the entire group is more or less at one testing than at another. Lamson's (201) data on fifty-six gifted children showed that as children they were for three years in the top centile of juvenile population on the Stanford-Binet Tests and that as young adolescents their Army Alpha ratings placed more than half of them in the top centile of adults, all of them being in the top 7.5 centiles of total adult population.

Brown's (149) Stanford-Binet data on 238 behavior problem children, ages twelve to eighteen, at the Chicago Institute for Juvenile Research showed variations in I. Q. similar to those of normal youth.

In England, Gray and Marsden's (186) report included seventy-six Stanford-Binet retests of children above twelve years of chronological age, but data were not reported separately for the older children. In one of Slocombe's retest studies (231) eight forms of a test were used. Since the correlation between members of pairs of forms was independent of intervals, he concluded that no group factors (due to practice) were present in the tests.

Woodyard (257) concluded that time (up to one year) had little effect upon variation in individual performance as measured by correlations. However, Slocombe (232) referred to the correlations of Baldwin and Stecher (123) which decrease as the intervals between testings increase. He held that application of the tetrad differences criterion of Spearman indicates that the factor causing the high correlation of early tests is not the same as the factor common to late tests causing their high correlation. Also, "conclusions drawn from comparison of scores at different ages are invalidated by the fact that the same thing is not measured at these different ages" (232:423).

Range of Individual Differences in Intelligence

Some experimental evidence has been reported tending to show an increase in the range of individual differences in mental ability during adolescence. Brooks (146: 119-28) discussed the statistical measures which should be used to solve this problem and summarized some of the studies. Jordan (65) reported the variability of group-test intelligence greater at thirteen than it was for the same individuals from six months to two and one-half years previously. Thorndike (240) also reported slightly increased variabilities from grades six to nine to twelve, to first year college and to graduate school. Since such school populations represent increasingly narrow selections, the variabilities for the entire popula-

tions of these age groups probably are considerably greater than Thorndike's estimates. Johnson (198) and Wilcocks (255) found evidence of an increase in variability with age. Thurstone (106) and Thurstone and Ackerson (105) found the absolute variabilities increasing during adolescence.

In the latter study (Chicago cases) a wider range of ability was tested than in the former (Burt's London school children) and the sigma at age twelve was 72 percent of that at age seventeen. Thurstone and Ackerson held that "according to the law of variability of test intelligence, the variability of any age group should be proportional to the absolute mean test performance of that age group" (105:574). Since the public-school populations would undoubtedly have higher mean test performance but smaller absolute variabilities than Thurstone's Institute group, their Pearson coefficients of variation probably would decrease during adolescence. This would indicate that the mean for successive ages increased more rapidly than the gross or absolute variability, that is, more rapidly than the "range of individual differences" in mental ability.

Sex Differences in Mental Development

The literature on sex differences in mental ability during adolescence consists for the most part of reports of differences in certain traits at one or more ages or grades, such differences being taken as evidence of sex differences in mental development. Selection and the differential effects of environmental factors make definite conclusions risky.

Allen (119), Goodenough (178), Lincoln (207), and Louttit (208) gave extensive bibliographies and summarized the literature up to 1925, 1926, and 1927 respectively.

Sex differences in learning and school achievement—In mechanical learning (substitution) Fisher (167) reported girls of thirteen excelling boys of thirteen, but boys of fourteen doing better than girls of fourteen. The small number of cases and the absence of retests prevent drawing definite conclusions. Thorndike (243) reported boys and girls doing about the same on an algebra test to quadratics. Pease (219) found boys making about 14 percent more errors than girls on an extensive series of algebra tests. Terman's (9) gifted girls did slightly less on equations and formulæ on the Hotz algebra scales and the same on problems.

Touton (245) found 61 percent of the boys exceeding the median geometry mark of girls on the New York Regents' Examinations. On the whole the girls were more variable. Webb (251) found statistically reliable differences in geometry scores in favor of the boys; 59 percent of boys exceeded the girls' median on form A, and 65 percent on form B. Data from Book and Meadows (139) and others agreed in showing boys doing somewhat better in tests involving mathematics, but with very marked overlapping.

In scholarship, as measured by high-school and college marks, girls seem to have better records. Crawford (157) found University of Idaho freshman marks slightly more favorable to girls, except in mathematics, but not in amounts statistically reliable. Paterson and Langlie (218) found freshman women at the University of Minnesota receiving better marks than the men. Book (138) found similar results for high-school students. Terman's data (9) on gifted students agreed with those of Paterson and Langlie, and Book, except that girls were markedly better than boys in ancient language and boys much better in chemistry. Boys were distinctly superior to girls on a test of scientific aptitude, but about equal on a test of fairmindedness. Brigham (143) on the College Board Scholastic Aptitude Tests found girls making higher scores than the boys, but the boys were more variable both on the first test and the retest a year later. Similar results were found on an earlier scholastic aptitude test (1926). Gerberich (174) found that boys constituted 59 percent of the gifted high-school seniors on Iowa High-School Survey; whereas they were less than 42 percent of the total senior group tested. But he believed a larger proportion of inferior boys drop out during the high-school years.

Sex differences in intelligence—Crawford (157) found negligible sex differences in intelligence among freshmen at the University of Idaho. Book (138), Broom (148), Colvin and MacPhail (155), Paterson and Langlie (218), Terman (9), and Whipple (254) reported data showing sex differences in intelligence slightly favorable to boys at high-school and freshman college levels, but usually by very small amounts. Graber (179) reported some data showing girls I. Q.'s higher than boys' except at highest age, seventeen, when boys' I. Q.'s are higher, but the number of cases is small. Davis (160) found no significant sex differences in a group of orphans, ages thirteen to twenty (no retests; $N=242$).

From retest data on nearly three thousand high-school students, Thorndike (230) noted certain differences at various ages. On the whole, they point to the conclusion that "the doctrine of an eventual male superiority delayed until the late 'teens by male lag in maturing should be very modest in its quantitative claims." In another study Thorndike (216) found boys slightly more variable than girls and more boys with very high scores, a result in accord with Gerberich (174) and others.

Goodenough (178: 459-660) concluded: "It appears, moreover, that the pattern or profile of abilities which tends to characterize either of the sexes remains relatively constant from early childhood to maturity. How these differences in pattern have orginated is not apparent from the data at hand."

Contrast between sex differences in mental ability and in school marks—Paterson and Langlie (218) found college freshman men superior to freshman women on college ability tests and Iowa Content Examinations, but the men received poorer college marks. Their results were in harmony with those of Book (138), Colvin and MacPhail (155), and others. Paterson

and Langlie (218) attributed the poorer marks "to a constant tendency to over-rate the achievement of girls." They also found that the use of objective tests and examinations reduced the women's superiority in marks. Courtis (156) showed that boys in grades seven and eight "must develop greater ability than a girl to receive the same mark," the superiority varying from around 10 percent to more than 100 percent.

Effect of Pubescence upon Mental Development

Various authors indicate their belief that accelerated anatomic or physiological development stimulates an acceleration in the rate of mental growth. More specifically, it has been asserted that the establishment of puberty speeds up the tempo of mental development. It is believed that since girls mature a year or two earlier than boys, either they are likely to have more actual mental ability for a short time in the early 'teens or they are likely to be relatively more advanced than boys. We have searched the literature to find the factual evidence supporting this opinion, but have found the amount disappointingly meager.

Baldwin and Stecher (4) and Murdock and Sullivan (214) reported data which have been interpreted as showing an increase in rate of mental growth at adolescence. The former is based upon Stanford-Binet retests, whereas the latter did not employ retests. Tulchin (246) could not find evidence to support this view. Doe-Kulmann and Stone (163), after a painstaking search through the literature, found 190 cases showing definite signs of puberty praecox, but for only sixty-two of them was any reference made to mental development or school performance. Data from standardized tests of mental development were reported in six cases. The evidence for intelligence was physicians' opinions which are highly unreliable as measures of intelligence. But at that, of the sixty-two cases, 21 percent were reported as above average, 38 percent at average, and 41 percent below average in intelligence. The authors concluded tentatively that there is "no evidence for genuine mental precocity regularly associated with any glandular disturbance underlying puberty praecox. Most probably the rate of mental development is either unaffected by the glandular disorder or is retarded" (163: 393).

Viteles (249) found no significant relation between age of pubescence and either intelligence or scholarship from non-retest data on 236 women students in a normal school, although he referred to the "spurt in mental development which seems to accompany pubescence." Layton (202) used teachers' ratings and estimates in studying the effect of pubescence upon various types of behavior and found that pubescent boys were less punctual; had poorer marks in school citizenship; were more disobedient, defiant, inattentive, and lacking in application; cheated more; and displayed temper more than the prepubescent boys. They were more attentive to girls than either the prepubescent or the postpubescent boys. Leal (203, 204) studied the effects of pubescence upon a wide variety of personality traits in four

thousand children nine to nineteen years old. She found that the higher I. Q.'s at any age belong to the earlier maturing children in 62 percent of the girls and 35 percent of the boys, and that evidences of religious awakening for boys and gregariousness for girls are related to maturing.

Gesell (175, 176) has presented in the case of two girls studied in the Yale Clinic the most complete data on various kinds of development in relation to puberty praecox. One matured sexually at the age of three years, six months and the other at eight years, three months. If sexual maturation is accompanied by accelerated mental growth, these cases should be excellent evidence. After extensive tests and examinations for several years, Gesell (176: 408-9) concluded:

> The nervous system, among all the organs of the body, manifests a high degree of autonomy, in spite of its great impressionability. It is remarkably resistent to adversity, even to malnutrition. This relative invulnerability gives it a certain stability in the somatic competition between the organ systems. It tends to grow in obedience to the inborn determiners, whether saddled with handicap or favored with opportunity. For some such biological reason, the general course of mental maturation is only slightly perturbed by the precocious onset of pubescence.

Miscellaneous Topics

Bowers (141) found scores on his tests of visual imagery independent (a) of age within a range from twelve to twenty-one years, (b) of sex within an age range of twelve to twenty-one years, (c) of I. Q., and (d) of ability in first year secondary-school subjects. Furfey (171, 172) reported a scale for measuring developmental age which, partialing out chronological age, yielded a correlation of near zero with mental age. Age norms to sixteen were derived directly, from years sixteen to nineteen by linear extrapolation. Howe (195) discussed emotional development with special reference to features of sex. Sweet (237) found boys of twelve to fourteen years of age showing high persistence of reactions as measured on his Personal Attitudes Test over a period of two weeks.

McElwee (210) found subnormal adolescents showing less emotional stability than normals, when measured by the number of individual reactions on the Kent-Rosanoff Association Test. MacNitt (211) found older pupils in high school more introverted. Stroud (235) reported a slight relation between economic status of parents and intelligence of children, the correlations between tax assessments and intelligence test scores averaging approximately .19 for ages thirteen to eighteen, N being 243. Hollingworth (192) showed that psychological weaning is a very important feature of adolescent development. Leal (205) also found evidence of this characteristic. Wheeler (253) set forth some of the important variations in emotional development during adolescence in three directions: psychological independence, the intensity of sex impulses, and the development of social, esthetic, and religious emotions.

2. PHYSICAL DEVELOPMENT IN ADOLESCENCE

The literature on physical development during adolescence is grouped under five headings:

1. Anatomic development, including height, weight, circumference and diameters of various parts of the body, growth of organs, ossification and dentition, curves of growth, etc.
2. Physiological development, including sexual maturation, breathing capacity, functional development of other organs and parts as evidenced by heart rate, blood pressures, respiration, etc.
3. Motor development, including muscular strength, motor skill, and speed and precision of voluntary movement
4. Metabolism
5. Organization of physical traits

Classic studies on physical development—At least a few of the earlier classic studies on physical development during adolescence should first be mentioned. Among them, Baldwin's work (128) is universally known. Its extensive retest data for several years on height, weight, vital capacity, strength of back, strength of grip, and chest girth, together with the intercorrelations between these physical traits for each sex and for each age up to seventeen, are still notable. The annotated bibliography of 911 titles of anthropometric studies throughout the world until 1920 and the extensive tables reproduced from this literature add materially to its value. It was the first extensive retest study in this field and is still a standard reference work. Attention should also be called to the studies of Boas (136), Burk (150), Godin (177), and Vierordt (248). Wellman (252) has given a good account of the important work on this problem.

Anatomic Development

Heights, weights, diameters, circumferences, and indexes of body build—Recent work on these phases of anatomic development includes that of Appleton (120), who studied Chinese children in public and private schools in Honolulu. His subjects included less than forty of each sex at each adolescent age until twenty. Data are given on standing and sitting height, length of upper arm, forearm, lower limb, thigh, height of knee, length and breadth of head, cephalic index, and variations of body proportions during adolescence. No retests were made. Baldwin (125) reported on thirty-seven anthropometric measurements of gifted children up to age fifteen and discussed sex and age differences, increments of growth, and indexes of growth. Girls appear more variable than boys in these tests. Baldwin, Fillmore, and Hadley (3) reported ten anthropometric measurements of approximately four hundred boys and four hundred girls, ages twelve to eighteen, in an "average" rural community in Iowa.

Baldwin and Wood (130) have brought together data from measurements on many thousands of children in their widely used weight-height-age tables. Baldwin (128) gave valuable retest data on height, weight,

chest girth, and other traits for approximately sixty boys and sixty girls at each age up to seventeen. Bean (132) gave data on the weight of heart, liver, etc., which show growth curves quite similar to those of Baldwin (128) for body weight. These data are obviously not obtained by the retest method. Bean (133) discussed adult male stature as shown by numerous studies of stature in Africa, Asia, Europe, North and South America, and the Pacific Islands. Boas' (137) retest data on stature of hundreds of boys agreed with Baldwin's (128) in showing that taller, heavier, or larger boys often mature earlier than smaller ones of the same chronological age. Berkson (135) from data on one hundred thousand men in citizen's military training camps, ages sixteen to twenty-one, found height, weight, and chest girth increasing during these years. It is not known what effect differential selection had upon Berkson's results.

In a two year retest of more than one thousand Oak Park, Illinois, children, Brown (164) secured data on weight, height, diameters and circumference of head, chest, and hips, arm span, and width of shoulders. Variabilities and sex differences are given for each age to fifteen. Increments of growth are similar to those reported by Baldwin (128). Collins and Clark (154) reported data on anthropometric measurements made on several thousand boys and girls of native white stock, third generation born in the United States, ages up to fifteen.

After studying several thousand children up to age fourteen, Faber (166) reported that no absolute criterion of normal nutrition based on weight is possible, and proposed a table of percentages for underweight and overweight in which age and sex are taken into account. He (166) also reported the normal range of weight for each height and age by sex up to the age of fifteen, basing his conclusions upon measurements of sixty thousand California school children. Gray and Ayres (182) discussed methods suitable for showing physical growth and gave the results of eighteen carefully made anthropometric measurements for approximately two thousand private-school boys and seven hundred private-school girls ranging in age from twelve to nineteen. They found boys' growth in height very slow after eighteen and girls' growth in stature slow after sixteen. They did not make retests.

Gray and Dodds (181) reported on auricular head heights of girls to age nineteen. The number of subjects is less than fifty at each of the years of adolescence and there are no retests. Gray and Fraley (183) reported height, weight, and chest girth of several hundred private-school boys to age twenty. They gave the weights for various heights; there were no retests. Gray and Gower (184) gave data, without retesting, on height and weight for several hundred adolescent girls attending private schools in or near Chicago.

Herskovits' (188) data on growth of colored boys included too few adolescents to make non-retest data significant. Hirsch (190) studied the cephalic index of American-born Russian Jews, Italians, and Swedes and

found little evidence of any marked change at adolescence. The number of cases at each age for each sex ranged from ten to one hundred (no retests). Jackson (196, 197) studied without retests the physical development of men and women students at the University of Minnesota. Jones (199) gave data on nearly seven thousand English boys, ages thirteen to eighteen, from measurements taken on groups attending a certain school in 1881-86, 1905-10, and 1921-23. His measurements indicate that the ratio $\frac{\sqrt[3]{W}}{H}$ shows suprisingly little change with age when applied to large numbers.

Porter (220) gave data on growth of boys until age thirteen only. He (221) found a seasonal variation in growth of Boston school children, those twelve to fourteen years of age gaining from three to four times as much weight between September and January as between February and June. Porteus (222) and Porteus and Babcock (223) reported on brain growth up to maturity, using cranial measurements of school children and university students. From these, brain volume was computed. Scammon (227) gave data on sitting height of several hundred Minneapolis girls which indicate (but not conclusively) that growth continues until age twenty-one, with a parapuberal increase in rate at ages eleven or twelve to thirteen or fourteen. Wallis (250) studied the relative growth of the extremities up to the age of eighteen. Woolley (258) reported retest data on height and weight of several hundred boys and girls, ages fourteen to eighteen, who quit school at fourteen to go to work. She found no indication that employment had any deleterious effect upon growth in height and weight. Wissler (256) showed age changes in cephalic index up to age twenty for Japanese, Germans, North and South Europeans, and Hawaiians. After the age of fourteen or fifteen girls' cephalic indexes are greater than boys'.

Anatomic development of gifted and feeble-minded—Hollingworth (191) found that forty-seven boys (mean Stanford-Binet I. Q. 153) who were measured annually for six years, ages at initial testing eight to ten years, did not "grow toward mediocrity in stature." She showed for each year the ratio of each child's stature to the norm for his age, sex, and race. These ratios are more than one hundred in forty of the forty-seven cases; the means of these ratios for the seven annual measurements range from 105 to 106. Smith (233) reported valuable data from the Harvard growth study with annual retests of several hundred feeble-minded children, ages twelve to eighteen, and several hundred children of normal intelligence, ages twelve to sixteen. Not only were the feeble-minded shorter than the normals at twelve, but the differences in stature increased as they grew older. Growth seemed fairly regular, but the feeble-minded, especially the girls, seemed to reach adult stature sooner than the normals. At twelve, feeble-minded boys were about as tall as eleven-year-old normals; at seventeen they were about the same height as normal fourteen-year-olds.

Ossification and dentition—Baldwin, Busby, and Garside (124) reported the results of roentgenograms of the epiphyses of the hand and lower

forearm, of the sesamoid bones of the hand, and of the bones of the wrist for several hundred measurements of boys and girls through age eighteen. Comparisons of boys and girls as to fusion of bony masses, rates of increase in ossification of bones, and variabilities are given. An anatomic index formed by dividing the sum of the areas of the carpal bones of the right wrist by a certain rectangle of the wrist was devised so as to eliminate the effect of general skeletal size. The anatomic index of girls was found to be significantly higher at all ages than that of boys, but after maturity the difference decreased.

Baldwin, Fillmore, and Hadley (3) reported on the dental development of farm children, using Cattell's method (152). Freeman and Carter (170) presented data on the ossification ratios of the wrist bones of twenty boys and twenty girls of each of the adolescent ages up to seventeen, showing that girls are more mature than boys at each age during adolescence. Cattell (152) found that the rate of dental development from twelve to fifteen was very slow, nearly all the permanent teeth having erupted by the age of twelve. Girls were in advance of boys. Prescott (224) also reported data on ossification ratios of boys and girls up to eighteen years of age.

Curves of growth—Individual growth curves based upon repeated measurements at annual or semi-annual intervals were given by Baldwin (128), Godin (177), and others. These are of great importance, for it is only by examining sufficient numbers of them that we can ever know the true story of development. Only repeated measurements can reveal what proportions of boys and girls fall into each of the three categories of growth in height mentioned or implied by Baldwin (128). Of the categories he concluded (a) that regular growth during preadolescence is followed by regular growth during adolescence, (b) that slower growth before puberty is followed by more rapid growth thereafter, and (c) by implication, that those whose growth is rapid before puberty grow more slowly thereafter. This is the method by which we can know whether taller boys and girls reach the periods of more rapid growth and subsequent slower growth at earlier ages than shorter ones. Conclusions on similar problems can be reached by repeated measurements.

Baldwin's data (128) indicate that the curves for stature and weight differ chiefly in that the latter are steeper and show positive acceleration until fifteen or sixteen; whereas the height curves are more nearly straight lines with earlier negative acceleration. Godin's (177) curves from thirteen and one-half to seventeen and one-half showed a break in the more rapid growth in height of French boys after fifteen; whereas the increments of weight increase from fourteen and one-half to sixteen and one-half.

Davenport (158, 159) gave an extended critical discussion of human growth curves for stature and weight. The curve for stature of males is, in general, related to the autocatalytic curve. Weight curves for males and females are similar to those for stature. Two notable periods of accelerated growth appear, the circumnatal and the adolescent. Curves are given show-

ing yearly increments of segments of stature for lower leg, thigh length, etc. Davenport (158: 212-13) holds that some segments increase rapidly at the same time that others increase slowly:

> The total growth is, as it were, the summation of growing parts, of organs, each following a more or less independent law. Not until we understand the changes in weight of the different parts of the body from the beginning of development to maturity shall we be enabled to give an adequate interpretation of the growth curve.

Boas (137), from retest data on many hundreds of boys, drew curves of growth in stature and rate with respect to the age at which maximum growth takes place. His graphs seem to indicate that the older the boy is when rapid growth begins, the slower the rate will be after the period of rapid growth.

Scammon (228) presented and discussed several curves of growth up to age twenty: height, weight of body, weight of spleen, kidneys, liver, pancreas, and of other organs, and area of heart silhouette. They resemble those of Davenport (158). He discussed and illustrated various types of curves, such as the lymphoid, neural, general, and genital, with their variations at time of puberty. Differences in the rates of growth of various parts and organs of the body are considered. Curves which indicate that the different organs have different rates of growth and different times of rapid growth are shown for the pituitary body, thymus, total brain, pineal, thyroid, suprarenals, etc.

Physiological Development

Sex maturation—Atkinson (122) gave data on sex maturation for several thousand high-school girls from which Brooks (146) computed the mean age of pubescence. Baldwin (127) reported results of a short investigation of the value of urinalysis as a means of determining, by finding out the presence of spermatozoa in the urine, whether sex maturation had taken place in boys. Further work, however, is necessary on this problem. Data on age of pubescence among boys and girls are found in Baldwin (128), Leal (203, 204), and Van Dyke (247). Gesell (39, 175) and Doe-Kulmann and Stone (163) reported on cases of puberty praecox in which sex maturation antedated the average age by as much as ten years. Leal's data (204) indicated that boys' maturation is approximately seven or eight months later than girls, rather than the generally-accepted one to two years. Morgan (213) found that 138 feeble-minded girls became pubescent at an average age of fifteen years, thus being somewhat retarded in physiological development. Leal (204) prepared a good review of literature on pubescence and discussed its stages.

Breathing capacity, heart rate, blood pressures, etc.—Data on development of breathing capacity during adolescence were reported by Baldwin (3, 125, 126, 128); by Brown (164) from two yearly measurements on school children to age fifteen; and by Collins and Clark (154) on chil-

dren to age fifteen. In these, sex differences were quite marked at the adolescent ages. Boys excel the girls at all times during adolescence. Baldwin's curves (128) show positive acceleration from prepuberty to age fifteen, with negative acceleration thereafter. The curves for vital-capacity-height index resemble those for breathing capacity, with the boys excelling the girls at all adolescent ages until seventeen, the highest age tested. The curves for vital-capacity-weight index are notably different for the two sexes, the boys' curve rising much more rapidly during adolescence and being notably higher at all times. Burlage (151) considered the systolic and diastolic blood pressures and the heart rate of several hundred adolescent girls.

Motor Development

Muscular strength—Baldwin (125) gave data on strength of grip for a group of intellectually gifted boys and girls up to age fifteen. He (3) also gave similar data up to age eighteen for farm children. In his classic volume (128), retest data to age seventeen were given for approximately sixty boys and sixty girls at each age. Boys excel girls at all ages and by increasingly large amounts in the later 'teens, the curves resembling those for breathing capacity. Variabilities also are given. Brown (164) reported results from two annual testings of strength of grip (right and left hands), showing the yearly increments of growth and the variabilities for each sex up to age fifteen. Additional data on the development of motor ability may be found in the reports of Atkinson (121, 122) on testing several thousand high-school boys and girls on tests such as baseball throw, 50-yard dash, potato race, hop-step-jump, rope climb, basketball goal shooting, or basketball throw, and in Brace (142) who used many tests to measure motor and athletic abilities of junior and senior high-school pupils and college women. A vast amount of work remains to be done to determine individual growth curves for many important motor capacities.

Metabolism

Benedict and Talbot (134) indicated the rates of metabolism until the establishment of puberty. Holt (193) gave the daily food requirements in calories for each age until twenty. His curves indicate a distinct upward trend from year to year and reach a maximum at age fourteen for girls and age sixteen for boys. Boothby and Sandiford (140) gave rates for each sex up to the age of twenty-one years.

Organization of Physical Traits

Numerous investigations have been made of the relationships existing between various measures of anatomic, physiological, and motor development during adolescence. Some of these report correlations between traits

after an interval of a year or more. Baldwin's (128) correlations between height (or weight) at one age and the same trait five or six years later are significant, ranging from .62 to .92. Brooks (145, 146) found height at one age correlating with height one or two years later nearly .90; for weight the correlations were above .95. Height and weight at one and two year intervals also correlate highly and positively according to several studies.

Baldwin (125, 126, 128) reported a great many correlations among height, weight, breathing capacity, sitting height, chest girth, strength of right and left arms, and strength of upper back for each sex and at each age up to seventeen.

Berkson (135) reported correlations between height, weight, and chest circumference for various groups of boys and men from non-retest data. He plotted curves to show the trends of the correlations with age. They are characterized by certain important points. The curve showing the height-chest-circumference correlations at various ages reaches a maximum at fourteen and then falls rapidly to a very low level by twenty or twenty-two; the low level is maintained thereafter. Height-weight correlations have a maximum point around six years, another high point at fourteen (but lower than the one at six), and then drop off rapidly. They remain, however, almost twice as high as the height-chest-circumference correlations. Weight-chest-circumference correlations show a high point at fourteen, drop slowly to twenty-two, then rise and remain above any former level. One may question whether the true relationships actually show such marked ups and downs as Berkson's results indicate.

Baldwin's correlations (128) vary also with age, but they differ greatly from Berkson's, especially for height-chest-circumference and height-weight. Since his results are from annual retests, greater weight must be attached to them in determining age changes in interrelationships among physical traits. Conclusive evidence on trends with age can best be secured by using carefully taken retests on sufficient numbers of carefully selected cases.

Brace (142) found various tests of motor abilities correlating from .17 to .80 with such tests of athletic ability as pull-up, fence-vault, running high jump, potato race, rope climb, running broad jump, and 75- and 100-yard dashes. Brown (164), Burlage (151), Cattell (152), Gray (185), Jackson (197), and Pasmore and Weymouth (217) gave correlations between various physical traits at the adolescent ages. Rogers (225) found age, height, and weight each correlating around .50 with an athletic index (made up of weighted scores on 100-yard dash, high jump, broad jump, and bar vault) for a large group of high-school boys. Lung capacity, right and left grip, back lift, leg lift, and pull-ups each correlated with the athletic index from .59 to .68. The best combination of age, height, and weight gave a correlation of but .62 with athletic index, whereas the seven physical

capacity tests correlated .81. Weight seems to be a more potent factor in determining strength of high-school boys than either height or age.

These studies reveal correlations varying from those well above .80 to those almost zero, indicating that physical development during adolescence is not a unitary thing. Brown (164) noted the need for more than one or two physical measurements if the physical growth status of the individuals is to be determined.

Stocks, Stocks, and Karn (234), using non-retest results, found no evidence of a sensitive relation between size of thyroid and physical development, size of head, and rate of growth or strength of grip among boys. They found some positive association, however, between size of thyroid and height, weight, rates of growth, strength of grip, and systolic and diastolic blood pressures in the case of girls, but none with pulse rate, hair color, or eye color. Thyroid and diastolic pressure curves were notably similar.

CHAPTER III

Physical Growth from Birth to Puberty

A very complete survey of the work of investigators on growth and development, both foreign and American, before 1921 was given by Baldwin (128). The present review of the literature on the growth and development of the child from birth to puberty will be limited almost entirely to the work of American investigators reported in the last five years. Since the literature is voluminous, it will be necessary to omit many investigations carried out by untrained workers or based upon inadequate samples. The first group includes work done by physicians, educators, and others without anthropometric training, or work reported by people who turned over the actual measuring to nurses or teachers. In the second group there are a large number of papers whose conclusions are based on very small samplings.

The most extreme case found was the paper by Rose and others (312), on the iron requirement in early childhood, in which they observed only one child (two years, seven months old) for a period of twelve days. From the findings on this one case, even though the experiment was reported as carried out "under the most favorable conditions," they assumed the responsibility of recommending "that children from two to three years of age receive at least .75 milligrams of iron per 100 calories." In a study of nutrition, Swanson (324) observed only two infants, one fed on powdered milk and the other on breast milk. From the data obtained, he concluded "it would appear from these investigations that a food high in minerals is not necessarily conducive to good health." Bakwin (262), in studying dehydration in new-born infants by correlating weight changes, skin elasticity, and serum protein concentration, based his conclusions on nine infants and made no attempt to find a possible sex variation. Willson (333) studied the postnatal development of the lungs, and made generalizations from the data of eighteen autopsy specimens in which there was one premature child, one aged thirteen, and one adult. He compared findings on these individuals and drew conclusions from the data.

In most instances where the number of cases was small, the two sexes were grouped together, undoubtedly to increase the number of cases in each age group. Naturally conclusions drawn from such data are unreliable and often worthless.

Methods and Technics of Measurement

Various methods and technics are at present available for investigators studying growth. The method most universally used is that of taking a series of physical measurements and, from the data thus obtained, studying the absolute and relative increments of growth of the body and its

segments. The selection of the measurements which will prove to be the most useful and significant is important and will vary according to the purpose of the study undertaken. The need for uniform methods and standardized instruments is well recognized by workers in the field of growth. Persons interested in obtaining reliable information on this phase of the subject should consult standard texts, such as those of Hrdlicka (291) and Martin (302).

A short general discussion of the problems involved in studying growth as well as a detailed description of the methods used is given by Scammon (227). He divided the methods used in analyzing data on growth into three general classes: pictorial, tabular and graphic, and analytic. Under each type the author gave a comprehensive discussion of the method and its use, as well as a review of the substantiating literature.

Within recent years several new methods have been proposed as a means of studying growth. In 1928, Clough and Murlin (272) described the use of stereoscopic photographs of the child taken at three month intervals. According to the authors, this method makes possible visualization of the growth and nutritional condition of the child at various stages. Moreover, accurate measurements can be made on the silhouettes, and correlations can be developed between growth of parts and other factors such as height and weight. Stereoscopic prints and projections, together with prints from superimposed negatives, give information which could not be expressed by anthropometric measurements. However, the method needs careful standardization.

Zook (339) recently opened up an entirely new field in physical growth by devising a new method of studying the growth cycle. This method, which measures the mass of the body and its segments by water displacement, takes into consideration and measures directly the volume of the part. The author called attention to the fact, however, that the method is subject to at least two errors: (1) it does not taken into consideration the effect of breathing on the upper segment; and (2) there is difficulty in accurately locating the division points between segments. The question should be raised, moreover, whether this method could be used with infants. Much experimental testing will have to be done to check the validity of this method before it can be recommended.

The use of roentgen-rays has recently furnished another means of studying growth. It offers certain advantages over other methods. For people with little or no anthropometric training it offers more reliable results than could be obtained by taking a series of physical measurements, and the records obtained are permanent and may be referred to at any time. Unfortunately, this method presents certain difficulties, of which one of the most serious is the distortion which occurs. A correction for the distortion in X-rays of the hand and arm for the age groups from two through eight years has been worked out by Ritt and Sawtell (309).

The only detailed work on X-ray technic for children which was located

has been compiled by Stunz (322) from data obtained at the Iowa Child Welfare Research Station. Tables of technics are given for taking X-rays of the extremities and heads of children varying in age from sixteen days to two and one-half years. She found that the technic used in X-raying infants varied with the age of the child rather than with the height or weight.

Differences in technics of measuring have led to significant variations in the work of authors, and a few investigators have carried out experimental measurements to test these errors. Mahalanobis (301), in analyzing head measurements from several sources, found an apparently significant difference in statistical constants caused by an inadequate definition of the amount of pressure used.

Boyd (269) gave an excellent discussion of the experimental error inherent in measuring the growing body. She stated that the literature indicates that the human body cannot be measured with a high degree of precision in spite of common agreement in technic and practice. Boyd also stated that height is measured with more reliability than other dimensions, and that the living body is measured with less precision than the dead. The degree of precision is different for different dimensions and for different measurements of the same dimension, and daily physiological linear reductions affect both stature and body stem. In analyzing the six measurements she carried out on fifty-six children between the ages of two and five years, she found four uncontrollable sources of error: (1) personal error of the examiner, (2) character of the end points, (3) daily physiological linear reduction, and (4) effect of age on the subject's ability to take and maintain the defined position.

Hejinian and Hatt (285) found differences which probably indicate a real difference beyond the chance error between the technics of the different technicians. Clark (275) made a study to determine the differences in measurements made on children clothed and nude. She found that when each sex group was considered as a whole, regardless of age, measurements made over clothes tended to be no more variable than measurements made in the nude. These conclusions, however, were based on children of a very narrow age range (seven to nine years) and are of restricted validity.

Scammon and Calkins' study (317) of fetal growth presented measurements for seventy-one external bodily dimensions on three hundred (on the average) selected human fetuses from 2.3 cm. to 54.4 cm. in crown-heel length. The parentage was chiefly American with a strong representation of Scandinavians and Russian-Jews. The study includes reliabilities of measurements, correlations, graphs, and a summary of previous work. The rectilinear relationship found between external fetal dimensions and body-length is shown to be not inconsistent with the law of developmental direction. The study contains valuable notes on methodology.

Hatt (284) compared the results on the Merrill-Palmer "biogram" (334) to staff and teacher ratings for a group of nursery-school children.

She found that the picture of the whole child as expressed in the concept of desirability agreed well ($r = .82$) with pooled biogram percentiles. The biogram data for physical traits are certainly more accurate and meaningful, and there is little point in trying to relate them to subjective estimates.

Recently Sumner and Whitacre (323) carried out an investigation to determine some of the factors which affect accuracy in collecting data on the growth in weight of school children. Their observations included comparisons made between the weights of children clothed and nude, effects of the time of day factor on accuracy of weight changes, and the effect that emptying the bladder before weighing has on the weight of the individual. These authors found evidence to indicate the necessity for always maintaining a known amount of clothing in weighing children whose growth is being followed month by month. They also indicate the need of weighing the same individual at fixed hours and of emptying the urinary bladder before weighing if the monthly body weight changes are to be followed. The results of this careful study should be taken into consideration by investigators studying monthly growth increments of children.

Time of day, location of anatomical landmarks, standardization of instruments, intervals for repetition of measurements are all factors which add to the lack of uniformity in methods and indicate the need for careful standardization of technics.

General Bodily Growth

The growth of the body as a whole is known to take place in a cephalocaudal direction. Davenport (159) stated that this growth is not a continuous process, but results from several growth promoting internal stimuli which act at different times and on different organs. From data collected by himself and other investigators, he derived tables of stature and weight as well as growth curves to support this theory of discontinuous growth. Scammon (283), in discussing growth, spoke of four types: general or skeletal, neural, lymphoid, and genital. These four types differ from one another in the time at which acceleration and retardation in growth occurs.

The study of growth may be attacked in one of two ways: by obtaining general averages from a series of measurements on large numbers of individuals, or by studying the growth of the individual from birth to maturity. The first method has been almost universally used, but it fails to bring out the variability and trends of growth of the individual and indicates, instead, only the general growth trends of populations. Thus Merrell (303) reported some highly interesting analyses of the effect of averaging physical measurements on a population (rabbits) to form a single growth curve. She showed that the true growth of an individual cannot be postulated from the composite curve. In populations of high variability the average curve undulates more than the individual curve, although this effect is

insignificant for the usual biological data. Rate fluctuations observed in average curves reflect the individual pattern. This cannot be said for skewness which may appear in the average curve without corresponding validity for the individual. Merrell's analysis also suggests that averaging skewed individual logistic curves may produce an artificial symmetry.

Growth standards—The question of how tall an individual should be or what he should weigh at any particular age has always been of interest, but in spite of this interest relatively few standards are available which give reliable figures. Average birth weights have been computed for infants by a few people, but practically nothing can be found concerning the heights of infants at birth. This lack of data on height can probably be explained in part by the fact that in infancy a child's state of nutrition can be determined fairly accurately by its weight at any particular age. This relationship, however, is not reliable after infancy and from that period on height in relation to weight is generally used.

Bean's study (268) of Old Virginians included a report on the stature of children from six to sixteen years of age from the Blue Ridge Industrial School and other schools in Greene and Albemarle counties. When the author compared his findings with those of other investigators representing twenty-eight groups of children from different parts of the world, he found that from birth to twelve years the Old Virginia[1] (white) children grow more than children from any other group. In considering only the Old Virginia children, Bean found that the stature of the girls exceeded that of the boys from seven to nine years and again from twelve to fourteen years. For these children growth of stature for both the girls and the boys was practically completed at fifteen years.

In order to discover the relation between weight at birth and early growth, Hammett (282) collected data from the records of the Boston Lying-In Hospital. He obtained records on 537 infants and found the normal birth weight to be between six and eight pounds. He considered this birth weight as an index of its relative physiological age. The paper is of interest, but his weight findings are of no value since he failed to consider the sexes separately.

Baldwin (128), realizing the need for individual growth curves in the early periods of life, obtained approximately five thousand weight measurements on babies who had been weighed at frequent intervals at the Baby Milk Fund Association in Baltimore. This material included weights of a sampling of one hundred white boys and one hundred white girls. The author found that the average weight for white boys (3,629 grams) was 85 grams less than for the white girls (3,714). Baldwin's findings on the birth weights of white infants are contrary to those of most other investigators who report the average weight of boys as greater than that of girls. See Ramsey and Alley (307), Taylor (326), and Yerington (337).

[1] The term "Old Virginia" refers to families which have been residents of Virginia for two generations or more.

Ramsey and Alley (307) computed the average weights of three hundred male and female infants born in the University Hospital at Minnesota and obtained an average birth weight of 3,391 grams for males and 3,276 grams for females. These figures are considerably lower than Baldwin's averages. They noted the postnatal loss of weight which occurs, and found the average initial weight loss to be 240 grams, and that it continued on an average for three days. The authors attribute this decrease in weight to the loss of large amounts of meconium, urine, and the amount of the vernix coseosa. This loss is regained in fourteen days in about 21 percent of the infants and by the twenty-first day in over half. They failed to find any relation, however, between the initial weight loss and size of the infants.

In order to find what relationship existed between the birth weight of the infant and the weight of the placenta, cord, and membranes, Aberle and others (260) obtained data on more than four thousand infants from the New Haven Hospital. By the use of correlation tables and regression lines, they found that the weight of the placenta is not a constant fraction of the weight of the child. While these weights influence each other to a large extent, the correlation coefficient indicates that there are undoubtedly other important influences which also exist.

Talbot (325) studied the growth of normal children and premature infants in terms of growth of different parts of the body. During the first year the head increases very rapidly in size in both sexes, and after that time it grows slowly up to the tenth year. The circumference of the head and chest is nearly the same until about eighteen months of age. Until the age of six years the rate of growth of the legs is practically the same in both sexes, but after six years the growth is greater in the boys. After charting the development of body proportions, the author found very little sexual variation. He observed that the most marked feature in the comparison of body measurements of premature infants with normal infants is that at birth the former is smaller in all respects.

By utilizing the changing variables of age and sex, Faber (166) attempted to construct a useful weight standard which would give an approximately normal range of weight for each unit of height, age, and sex, computed so as to have a uniform significance in each case. With this in view he obtained the weights of over sixty thousand school children of San Francisco, five to fifteen years of age. These data were arranged according to height, age, and sex. Frequency distributions were made, the 10 and 90 percentile points determined, and a table constructed for each unit of height, age, and sex to show the approximate range of weight that would take in the central 80 percent of cases. With such a table, underweight and overweight are defined as deviations greater than 90 percent from the normal of children of like height, age, and sex. The author recognized the fact that this standard undoubtedly allowed really undernourished children to escape attention, but he held this to be true of any method dependent on weighing and measuring alone.

Until recently one of the best indications of a child's physical status has been a height-weight relationship. Height-weight-age tables based on the average measurements of large numbers of individuals are at present available on children from birth to puberty (264, 292, 293, 335). One of the most extensive investigations of children under six years of age was made by Woodbury (335) for the United States Children's Bureau. Data used in the report were selected from over two million records of heights, weights, and other observations on white and negro children from one month to six years of age. The report is divided into two parts. The first contains a record of the average heights and weights of children from various parts of the country. The second is based upon data from California and New York City and shows the prevalence of defects and the relation of these defects to height and weight. An excellent summary of his findings is given by the author in a paper published in 1925 (336).

Height-weight tables are available for children which take into consideration certain major factors (geographical locations, nationality, and socio-economic status) which are known to influence the physical status of the individual. Among the best known standards for American-born children of school age are the tables published by Baldwin and the Iowa Child Welfare Research Station. In 1925 Baldwin (264) published weight-height-age norms for children between the ages of six and nineteen years derived from measurements on 498 boys and 437 girls. In 1929 the Iowa Child Welfare Research Station (293) published tables of measurements of 150 boys and 167 girls from three to six years of age. The measurements were made monthly, and the tables represent averages of 512 measurements on the boys and 568 measurements on the girls. While the children on which these measurements were taken are from a rather favored environment, they may be considered as typical for children attending preschool or nursery-school groups. The Iowa Child Welfare Research Station (292) compiled tables giving the means, standard deviations, probable errors of the means, and coefficients of variation of eleven physical measurements on infants from birth to three years. They were based on 1,300 measurements of infant boys and 1,003 measurements of infant girls. These tables were intended as a supplement to the averages for children from three to six years of age, which were published in 1929. However, they present a possible error for height and sitting height, since it may be assumed that some of the figures from which the averages were compiled represent measurements taken in the supine position, while others were taken in the upright position.

The tables compiled by the Iowa Child Welfare Research Station (292, 293) were considered inadequate by Gray and Fraley (183) for judging the physical development of boarding and country-day-school children. These authors accordingly compiled standards based on 1,016 measurements of boys from private schools. They found that these boys exceeded in stature and chest girth the measurements reported by Baldwin (125) for

gifted children. When the relationship of weight to height is considered, they represent a very slender type. Gray and Gower (184) presented height-weight standards for private-school girls based on measurements of 1,050 girls in private schools in or near Chicago.

Wilson and others (334) compiled data on the following measures for nursery-school children (a selected group mentally, socially, and physically): standing height, weight, weight for height, weight-height index, stem length, recumbent length, and stem-stature index. Measurements are in English units with the number of cases varying from twenty-five to seventy-seven. The materials are presented in percentile tables computed from the Merrill-Palmer nursery-school group. The value of assembling the complete physical, mental, and social data on a child as percentiles to form a "biogram" is stressed. But comparative percentiles do not appear promising in advance of a better knowledge of what is really optimum for the human growth pattern.

Wallis (331) based results and conclusions on an extensive study of private-school children from two to eight years of age. After careful analysis of her data the author found that the average stature of young children has an economic or environmental significance which masks European race distinctions. The absolute amount of its annual progress seems to rise and fall in alternate years. The season does not affect the amount of increment. The sex difference in adult stature appears largely as a tendency for boys to be taller than girls between the ages of two and eight years. Annual weight increments, likewise, have alternate years of greatness. The author was unable to find any evidence of seasonal variation in the New York children. Wallis stated that although the stem-stature index grows steadily smaller during childhood, it does not constitute a criterion of maturity for rating the individual. Nevertheless, it is of considerable value as a descriptive method. Her findings on the growth of stature, weight, stem-length, trunk-length, lower and upper extremities, span, shoulder, pelvis, and head and face indicate that their growth proceeds according to age, sex, and stature. In studying ossification she found that the factors governing the behavior of carpals, tarsals, epiphyses, and diaphyses during the growth period from two to eight years are age, sex, race, economic status, the individual's total size as measured by stature, and function.

In a comprehensive discussion, which covered the work of seventy-six investigators, Bardeen (265) described a number of ratios which are helpful in completing the picture of anatomic growth from infancy to adulthood. He emphasized the importance of sitting height, length of legs, and relative adiposity. Limiting factors applying to all usages of height-weight indices in the measurement or prediction of human growth include physiological age, sex differences, inherited individual and racial peculiarities which may be manifested at any period, and the influence of individual habits and environment.

Body types.—The use of height-weight-age tables has recently been subject to much adverse criticism because they fail to take into consideration the build or type of the individual. Realizing this inadequacy Lucas and Pryor (299) have attempted to find a new measure of nutrition which would eliminate this difficulty. They chose stature and bi-iliac diameter as the two measures of skeletal dimension which are least affected by the overlying soft parts. They measured one thousand children of both sexes, from birth to seventeen years, and computed the width-length indices which they compared with weights. They concluded that standard deviations indicate weight varying from the height-weight table ideal twice as much as the width-length index varies from the average at each age when both are measured in percent. They pointed out that an intermediate group (indices 150 to 180) contains 80 percent of the series. Those indices which lie on either side of this intermediate group are considered as normal groups of different physical types, linear and lateral, instead of representing either under- or overweightness.

In 1929 Bakwin and Bakwin (263) undertook an investigation with the idea of describing the various types of body build in infants and of noting some of their disease associations. They observed only sixty male infants ranging in age from two weeks to fourteen months. From their investigation they concluded that in infants, as in adults, it is possible to distinguish linear and lateral types of body build. They found the nutritional state to be a salient characteristic of body type in infants as well as in adults. Infants suffering from malnutrition tended to have a linear type of build while infants with eczema were of the lateral type. The intermediate group was composed of tetanic infants. While the authors stated that they made allowance for certain errors in measurements they failed to tell how they made these allowances, so the reliability of the data should be questioned.

An investigation concerning the value of the stem length-recumbent length ratio as an index of body type in young children was carried out by Hejinian and Hatt (285). Measurements were made on children from eighteen months to sixty-six months of age in the Merrill-Palmer School, and the stem length-recumbent length ratios were arranged into percentile distributions in order to measure variability. From the percentile tables it is evident that the ratio decreases progressively with increasing age from two to five years. By the use of trend lines it was shown that 72 percent of the children remained in approximately the same percentile rank during the years from two to five. The authors thus concluded that, within certain limits, a child tends to retain during preschool years the same relative percentile rank in stem length-recumbent length ratio as compared with his chronological peers, and that the ratio is a valid index of body type during these early years. However, it is not known if this body type persists throughout life.

Proportional growth—Various authors have studied the proportions of the body during growth and on correlations of different physical measurements. Baldwin (126) derived new norms for breathing capacity devised

to give height as well as age due consideration. Judged on a statistical basis, he considered a child's breathing capacity abnormal if it deviated 13 percent from the average for his height and age. The mean breathing capacity was greater at all ages for boys than for girls. Wallis (250) reported the relative growth of the extremities in relation to age, sex, stature, and hereditary factors. Observations for the study were made on children from two to eighteen years who attended the preschool of the Iowa Child Welfare Research Station and the University elementary and high school. She concluded that the relative and absolute growth of the extremities is dependent even more on stature perhaps than on the obvious factor of age. Sex, the individual's build, and the type inherent in his family lines are factors apparent from early childhood to subadult age.

Growth of segments—Studies of the cephalic indices of American-born children of South Italian, Russian-Jewish, and Swedish parentage were made by Hirsch (190). Measurements were obtained of the heads of over two thousand children ranging in age from six to fifteen years, in the public schools of Brockton and Chelsea, Massachusetts. After determining the average and standard deviation of the cephalic indices of each group, the author compared his findings with those of Boas on Jewish and Italian children. He found that Neapolitans and other South Italians of his group tend to be more dolichocephalic, that is, long headed, than Boas' Neapolitan-born group. In studying the Jewish child he found a lowering of the cephalic index by 2.5 to 3.0 points in one generation. There was no appreciable change, however, in the cephalic index of the Swedish children in two generations. The author was aware of the fact that the small number of cases measured limited the value of his findings.

Gray and Dodds (181) measured 479 girls from private schools in or near Chicago in order to determine their auricular head heights. They used the Western Reserve head spanner devised by Todd. From the data obtained they constructed a table showing the mean auricular head heights for each age taken at nearest birthday. The height was found to vary at different ages from 125.9 to 130.8 millimeters, with an average for the entire group of 127.8 millimeters.

Growth of organs—Relatively little has been done in this country in obtaining the growth curves of various organs. It is practically impossible to obtain accurate measurements on most of the organs in the living by present methods. Most of the data available at present have been obtained from autopsy material or bodies in anatomical laboratories, and the question immediately arises as to the advisability of basing norms on these data. Weights are particularly unreliable from such sources since the amount of drying of the organs cannot be determined, and they are particularly affected by the state of health of the individual at the time of death. Even in cases of sudden death due to accident the question of the amount of blood in the various organs and its effect on the weight is important.

Ellis (277) in carrying out investigations on structural changes in the human cerebellum from birth to old age, found that in the newborn the human cerebellum is relatively small compared to the cerebrum, but that it acquires at fifteen months approximately the same relative weight which it shows during the rest of life. Moreover, he found that the relative weight of the cerebellum did not vary to any significant degree with the stature, sex, race, or intelligence of the individual. Scammon and Dunn (318), likewise, carried out investigations on the cerebellum in infancy to test the concept which attributed the rapid growth of the cerebellum in infancy to the development of muscular coördination and activity which occurs at this time. They presented tables giving the volume of the cerebellum in the fetal period and the weight of the cerebellum in the first year, as well as the absolute and percentage monthly increments in the volume and weight of the cerebellum. Unfortunately, the authors failed to treat the data for sex differentiation, and no mention was made of the number or age of the subjects used. The authors devised empirical formulas for the relation between cerebellum volume and body length in the fetal period, between body length and age in the fetal period, and between cerebellum weight and age in postnatal life.

Considerable interest has been shown by investigators concerning the growth of the thymus. An excellent study of the thymus, giving a very complete review of the most recent data on its anatomic and histologic structure including also the theories as to the production of the thymic syndrome, was given by Shannon (319) in 1930. Another comprehensive review of the literature on the thymus was prepared by Boyd (270). This paper presented norms for weight and gave the range of the normal glands from birth to ninety years.

In 1925 Ziskin (338) examined and measured teleroentgenograms of the hearts of more than four hundred children ranging in age from four to sixteen years. From these data he computed ten average measurements and ratios between measurements of the normal heart in childhood. Tables are given of these standard measurements arranged by age and height, but no sex difference was taken account of in the sampling. DeBuys and Samuel's (274) study of the roentgenograms of four hundred infant hearts is of no value as a piece of work on growth. No sex variation was given and methods of measurments were not disclosed. In 1928 Lincoln (296) published the results of investigations carried out on normal school children of the City and Country School of New York City in an effort to compile norms and to study certain pathological heart conditions. This paper, while of interest to anthropologists as a source of standards for normal hearts, is of particular interest to the medical man. The examinations were made under excellent general conditions, but attention should be called to the fact that the group studied were from a favored environment and that the number of cases in each age-sex group was small.

In the second paper of the series, Lincoln and Spillman (298) determined the normal size of the heart in children of various ages and the normal relationships between the transverse width of the heart, height, and width of the chest. An attempt was also made to classify the shapes of normal hearts. The material consisted of yearly X-rays of 246 normal, private-school children, two to thirteen years of age, for a period of seven years. While here again the age-sex groups are small, the measurements and X-rays were taken under well-controlled conditions. The findings of particular interest were: (1) until seven years, the girls' hearts are smaller than the boys', but after eleven years this condition is reversed; (2) there was found to be a closer correlation between height and size of heart than between age and size of heart; (3) they found four main types of shape of hearts in the child as in the adults, but the shape of the heart in children does not bear a constant relation to type of body build. Changes from one type of heart to another were uncommon, occurring in only 6 percent of the cases. A strong familial resemblance in the heart shadow was found in one-half the family groups. The third paper of this series by Lincoln and Nicolson (297) was carried out in an attempt to establish norms for each age period. Sex and hereditary characteristics were also observed. This investigation was based on the examination of cardiograms and here, too, the authors often found a marked similarity in the electrocardiograms of members of the same families. They found a sex differentiation in the electrocardiograms of children.

Bean (267) in a study of the postnatal growth of the heart, kidney, liver, and spleen weighed these organs and prepared tables accordingly. But findings were based on autopsy material and cannot be considered reliable.

Measurements of developmental stages—Pubescence is an important factor in determining the developmental state of the child. In studies of growth, however, this period and its relation to the growth cycle has been neglected, due probably to the fact that most studies of growth have been based on averages computed from a few measurements on numerous individuals rather than on a series of observations on individuals over a long period of time. By the former method it is impossible to obtain the period at which pubescence occurs. Another difficulty is in estimating exactly when the prepubescent child enters pubescence. Crampton (273), after collecting data on New York City high-school boys, concluded that chronological age should not be used in the study of growth. He decided that the important factor was whether the child was in the stage of pre- or post-pubescence, since growth rates are dependent on the pubescent period rather than age.

Anatomical age: ossification—The stage of development of children may be measured by the degree of ossification and the dentition as well as by pubescence and chronological age. By the use of X-rays it has become possible to study the progressive ossification of the bones in individuals as development proceeds, and within recent years various investigators have become interested in this study of the maturation of the skeleton. Adair

and Scammon (261) took X-rays of one hundred newborn infants in order to determine the condition of ossification centers of the wrist, knee, and ankle in newborn, and to find their interrelationships and particularly their relation to the maturation and size of the child. Examination of the X-rays and tabulation of the data obtained showed that the inferior femoral epiphysis was present in 98 percent of the cases. The two in which it was absent were premature. The superior tibial epiphysis appears later than the inferior femoral, being present in 75 to 80 percent of all cases in full-term infants. Thus the superior tibial epiphysis is a better test of maturity than the inferior femoral, and its presence in five out of six cases indicates that the child has passed the ninth fetal month. The cuboid (a tarsal) was present in about three cases in five in the full-term infant, while the capatate (a carpal) appeared in 15 percent, and the hamate (a carpal), in 9 percent of the cases in their series. The authors found a close relation existing between total body length and frequency of ossification of centers observed, but the correlation between body weight and frequency of ossification was not as high. There was evidence to indicate that even though the weight and other dimensions of the female are less than the male, ossification proceeds more rapidly in the former. The authors failed to find any relation between onset of puberty and the rate of ossification in intrauterine life.

The existence of a sex variation in ossification was verified in an interesting paper by Hess and Weinstock (287). The authors examined X-rays of about five hundred newborn infants from the Sloane Hospital for Women. They found more centers of ossification at birth in the females than in the males and a more frequent occurrence of centers was found in heavier than in lighter babies. A racial difference was apparent in the more rapid development of centers in the negro children. Due to insufficient data it was impossible to determine the effect of season. The authors failed to find that the rate of development of the centers was affected by order of birth; but the data were too limited to give any value to this observation, except as they tentatively confirm the finding of Adair and Scammon (261). Hellman (286) carried out an investigation on the ossification of epiphysial cartilages in the hand. X-rays of the right hands of sixty girls from the Hebrew Orphan Asylum were obtained at yearly intervals for four consecutive years and studied. Morphologic changes were recorded and four stages were observed in the ossification of the epiphysial cartilages of the hand. Limited physical measurements and dental examinations were also obtained. The author found that ossification of the bones of the hand lasted less than three years starting any time between twelve years, thirty-six days and twelve years, eleven months; and ending anywhere between fourteen years, three months and fifteen years. The ossification is first completed in the distal phalanges, then proximal ones in order of their position.

Baldwin, Busby, and Garside (124), undertook a study of the X-ray findings of the bones of the wrist, epiphyses of the long bones of the lower forearm, and hand (including sesamoid bones) in order to derive a general

idea of the anatomic development of the child. Data were obtained from approximately thirteen hundred X-rays of forearms and hands of children from birth to maturity; records of physical measurements were included. Areas of the carpal bones and of the wrist were obtained by use of the planimeter and sliding caliper, while inspection gave certain facts concerning time and order of appearance of the epiphyses and carpal bones. After careful consideration of their findings, the authors concluded that boys and girls live in two different calendars of physiologic and anatomic ages, and their periods of accelerated development and final periods of maturity occur at different times.

An extensive study of epiphysial union and skeletal differentiation is being carried out by Todd (329). His first article (328) was a general discussion of a detailed and comprehensive analysis of mammalian epiphysial union, accompanied by a rather exhaustive investigation of this problem in man. He indicated the need of checking observations on X-rays by anatomically examining the very bone roentgenographed. This is practically impossible and is not complied with even by the author himself. The second paper (327) of Todd's series dealt with the anatomical features of epiphysial union. In this rather general treatment of the matter, Todd divided the maturation and union of epiphyses into nine qualitative stages. The third Todd report (330) was likewise qualitative. It gave in detail ossification in the knee, hand, and elbow in a series of white males. This description is a summary of illustrative material against which roentgenographic records may be checked. A general criticism which may be applied to these three papers is the vagueness which prevails. The lack of exact data on the number of children studied and the number of cases in each age group is characteristic. There is, moreover, considerable repetition throughout the three articles. Unfortunately, the conclusions are not drawn from series of X-rays on individuals throughout the entire period of observation. But the discussion is interesting and should stimulate further investigation of this problem.

Todd (329) found that there was a definite human pattern in skeletal development in both males and females which is not hidden by sex modification. He pointed out that confusion arises if inception of ossification is taken to be related to epiphysial union. His discussion indicated that exact measurements of skeletal maturation are a fruitful base for the study of sex, race, and disease factors in human growth. "Average" in such maturation covers a wide range. Todd recommended ± 3 S. D. for a population of a given age. Sawtell (316) worked out the contrasting sex differences in the ossification and growth of the radius as expressed by the transverse diameter of the epiphysis and diaphysis with their indices. She also took measurements on cranial diameters. The data were collected in most part from X-rays of 112 boys and girls whose ages ranged from six months to eight years, five months, from the City and Country School, New York (some siblings of school children were available for measurement);

235 children from the Cleveland public schools (largely of Sicilian parentage); and twenty-eight Sicilian babies from lower East Side of New York. The material from these three groups was treated separately. This study indicated a sex difference in bone growth consisting in the acceleration of ossification seen in the female. Also greater breadth of the radius and larger head size are evident in the male at an early date. Sawtell (315) in a study based on four hundred children indicated the existence of a definite interrelationship which occurs between ossification and gross bodily size, but found that it was not as great as the correlation between the actual growth of bone and the stature and weight of the child. She (314) also described various irregularities appearing in ossification centers and the location of epiphyses.

Dentition—Pyle and Drain (306), in a study of the dentition of the preschool child, examined 373 children eighteen months to seventy-seven months of age attending the preschool laboratories of the Iowa Child Welfare Research Station. They listed the number of teeth erupted and shed, cavities, fissures, and abnormalities of the teeth and observed the general condition of the mouth. The authors failed to find any sex difference in the number of cavities. Cavities were found most frequently on the occlusal surface of the teeth with the condition more prevalent in the upper teeth than in the lower ones. The molars had the greatest number of cavities. They were unable to demonstrate any relationship between the general condition of the mouth and the occurrence of cavities. Franzen (278) reported an intensive analysis of the first molars and the second bicuspids, or their precursors, and the deciduous second molars in a random group of ten-, eleven-, and twelve-year-old American-born white children measured by dental hygienists of the school health study field squads during the school year 1927-28 in seventy different cities in thirty-eight states. The most striking findings are (1) that decay is periodic and is a function of the individual organism and not the tooth, and (2) that present dental correction is palliative and neither preventive nor curative. As a result of these statements the Oral Hygiene Committee of Greater New York (305) published a reply consisting of "an analysis, a protest, and a correction." After a careful analysis of the material they found that some of the statements were false, while others were misleading, and those which were correct had been known to men in the profession. They branded the articles as being "unreliable, unwarranted, and misleading."

A more extensive study of dentition is reported by Cattell (271). The findings are based on data from 11,656 examinations including unselected school children (8,377 of North European descent, five years, six months through fourteen years of age; 463 Jewish children, seven to ten years; 1,936 Italians, six years, six months to twelve years of age) and 880 north European feeble-minded children ranging from eight years, nine months to fourteen years, nine months. After careful consideration and statistical treatment of the data Cattell noted several interesting facts. She found that

the teeth which appear while the child is young erupt at a more uniform age than those which erupt later. Concerning the differences in time of eruption, Cattell was unable to report any constant tendency for the teeth of one side of the jaw to erupt before those of the other. A sex difference in dental development was found to exist which is marked by the more precocious development of the teeth in the girls of the racial groups studied. She also noted a small racial difference in dental development of these three racial groups. Her findings were negative with respect to the relation between intelligence and dentition. Cattell (152) devised a scale for measuring dental development. The standards which she derived were compiled from data on 7,835 children of North European descent, no Jewish children included. These standards were based on the total number of permanent teeth which had broken through the gums, regardless of their degree of development. Three graphs are included in the article. The first gives the median number of permanent teeth erupted at each age; the second, the dental age norms for each number of teeth; and the third, the dentition quartile deviations and percentiles for different ages.

Nutrition—One of the most important factors known to affect the growth and development of the individual is nutrition. The space allotted here does not permit a discussion of this extensive field of investigation and, fortunately, it is unnecessary. A comprehensive review and evaluation of the work has been prepared by Roberts (311). A composite discussion of the field of nutrition is found in a publication of the White House Conference on Child Health and Protection (332). This work represents the combined opinions of authorities in this field and is an attempt to define the existing knowledge of nutrition in terms of a theoretically complete knowledge. An excellent general review of recent work on the effects of inanition and of malnutrition on growth and structure is given by Jackson (294). The material is treated from a morphologic point of view; the author mentions the physiologic and biochemical aspects only incidently. Anyone interested in the physiologic and chemical views should consult the work of McCollum and Simmonds (300).

Closely related to the study of nutrition and growth is the study of the metabolism of the individual. The work in this field is extensive and the reader is referred to the classic by Murlin (304) which appeared in Abt's *Pediatrics.* Further discussion of the field of metabolism is found in the White House Conference publication (332) which reviews the more recent literature on the subject.

Blood pressure—Richey (308) presented measures of blood pressures of normal children with the corresponding effects of age, physical development, and sexual maturation. Data for the study were obtained from measurements on 1,147 children, about 20 percent of Jewish extraction, from the Laboratory Schools of Chicago University. Tables are given of the average systolic, diastolic, and pulse pressures of non-Jewish boys and girls between the ages of five and nineteen years of age. The average blood

pressure of children increases with age, except in girls where it tends to decrease after the sixteenth year. A wide variation in blood pressure was found for normal children of the same age. A significant difference was found between the pressures of the two sexes.

Endocrinology, a field which has been recently developed, is known to have an important bearing on the growth and development of the individual. But careful measurements on large series of children to determine the effect of abnormal functioning of particular glands on specific growth patterns and the general development of the individual are at present unavailable. Factors which initiate these glandular disturbances are also unknown. Nevertheless, an extensive literature on ductless glands exists, consisting of descriptions of the growth and development of the individual glands as well as their physiologic actions. Excellent reviews of the works on the various glands can be found in *Endocrinology and Metabolism* (266). An interesting general discussion of the subject in relation to the growth and development of the individual is given by Hoskins and Talbot (290) in the preliminary reports of the White House Conference on Child Health and Protection.

Growth among Negroes

Very little was found in the literature concerning the growth of negro infants. A criticism which may, in general, be applied to all work on negroes is the lack of consideration of the amount of race mixture in the group. This factor is of primary importance and the value of the work in which this question is not considered is questionable. Baldwin (128) reported observations on one hundred colored male and one hundred colored female infants from birth to fifty-six weeks. He found the negro girl infants to be on an average sixty-eight grams lighter than the colored boy babies. This difference continued to be slight until about the sixteenth week. By the thirty-fifth week the boys had almost doubled their weight of the sixteenth week. This sex difference became less and less until by the fifty-second week the weights of boys and girls were again about equal. Dodge (276) compiled data on 290 male and 306 female negro infants from Cleveland ranging in age from three to eighty-three weeks. The growth curves which he derived agreed closely with Baldwin's findings, except that the male curve was a little higher and the female curve slightly lower. In concluding, the author called attention to the need of studying the negro child in his native southern environment if a true picture of his growth was to be obtained. Although Dodge was careful to check certain factors in technic, he noted possible sources of error in his own data.

In 1928 Sterling (321) reported the results of an extensive study of more than five thousand negro school children from Atlanta, Georgia, whose ages ranged from six to fourteen years. From eight to nine years through fourteen years the negro girls were found to exceed the boys in standing and sitting height, while the girls excelled the boys in weight in the period

between ten and eleven years through fourteen years. The author found a slight difference in the diameter of the chest in negro boys and girls. In the latter the chest is broader after eleven years than it is in the former although it is more shallow. The cephalic index of the girls is slightly higher than the boys, except at ten and eleven years. Thirty-one percent of the children were entirely free from dental caries, while 33 percent had only one or two defective teeth. Between the ages from six to thirteen or fourteen years the teeth were more perfect in the female than in the male. The author rated the nutritional status of 45 percent of the children as either good or excellent, with the girls having the advantage over the boys.

Royster and Hulvey (313), realizing the fact that the Baldwin-Wood Standards were not suitable as a means of evaluating the physical status of negroes, carried out investigations on the relation of weight, height, and age in negro children. The tables were based on measurements of 8,876 urban-school children in Richmond, Virginia. Height-weight-age standards are given for boys from six to eighteen years and for girls from fifteen to eighteen years. In comparing their standards with the Baldwin-Wood norms, the authors found, in general, that negro boys from six to sixteen years are shorter than white boys; that negro girls are taller than white girls from six to seven years, but from eight years on negro girls are shorter; that negro girls mature slightly earlier than white girls. Considering their own data separately they found that up to six and one-half years of age the negro female is slightly taller than the negro male, from six and one-half to ten years she is slightly shorter, from ten to thirteen and one-half years she is definitely taller than the boy, and finally at fourteen years the negro boy again passes the girl in height and thereafter retains the lead. The value of this study is uncertain since no consideration has been taken of the degree of race mixture which undoubtedly occurs. However, it is hoped that this study will serve to stimulate interest in a study of the negro in which this factor will be taken into consideration.

After studying 397 negro and 936 white children (six to sixteen years) from the rural districts of Alabama, Smillie and Augustine (320) considered the lower vital capacity of the negro child a racial characteristic. This markedly lower vital capacity of the negro as compared to white children was found in both sexes and for all age groups studied. When the authors calculated the vital capacities of the two races from the stem-length it was only about 10 to 15 percent lower in the negro as compared to the 15 to 20 percent difference which was found when it was calculated from the surface area. Roberts and Crabtree (310) measured vital capacity, standing height, weight, and stem-length of 1,254 negro and 1,564 white children. They found that in negro children the vital capacities were definitely lower than in white children of the same age, body weight, and standing height. But when children having the same stem-length were considered, it was found that the vital capacity was practically the same for both negro and white children.

Growth in Motor Development

The investigation by Jersild (295) raises the following question: Is it possible through special training in early years to raise a child's capacity beyond the level which would be achieved in the normal process of growth? The equivalent group method of experimentation was used in studying mental, motor, and musical performances. The children ranged from two to eleven years in age. There were 121 practice and 127 control subjects distributed among the various experiments who completed the initial tests, the training series, and the retests at the end of training. Practice was given three days each week while school was in session (two or three days per week in the case of one experiment) for a period varying from three and one-half to six months. In all experiments the practiced children showed some advantage over the controls at the end of training. On later tests the practiced children maintained this lead in only one experiment. The gains produced by practice in these experiments were relative to the child's initial capacity. Improvement was made within limits apparently determined by the child's degree of maturity. Practice did not go beyond these limits to bring about changes normally identified with growth.

One of the objectives of the investigation by Hicks (288) was to discover the effects of systematic, well-motivated practice upon the ability of young children to hit a moving target with a ball. The subjects of the investigation were sixty children ranging in age from two years, seven months, to six years, five months. The children were given a Moving Target Test devised by the author, the Blackhurst Strength Test, the Perforation Test devised at the Iowa Child Welfare Research Station, and the Wellman Tracing Path Test. They were then divided into two equated groups of thirty each upon the basis of the mean and standard deviation of scores on the Moving Target Test. The thirty children in the practice group were given the Moving Target Test once each week for a period of eight weeks. In general, for the complex skill studied and for the amount and kind of practice given, the extra practice given to the practice group resulted in but slight improvement as compared with the control group. The author (288:73) concluded that "for the development of complex motor skills in preschool children, maturation and a general environment in which many experiences are possible are much more important than systematic practice."

Gates (280) and Gates and Taylor (279) conducted an experiment relative to the nature of improvement resulting from practice in the simple motor function of tapping on a paper with a blunt pencil. Their subjects were eighty-two children ages four to six years. Each child took three daily tests of thirty seconds per test with short rest periods intervening. At the end of a preliminary test period of eighteen consecutive days when all children seemed to have reached their limit of improvement, two equated groups were formed and one group given seventy-six consecutive days further practice. Both groups received practice again at the end of seven-

teen days and were given a retest in six months. The results showed rapid initial improvement, steady gain for the long period of practice, and no advantage for the practice group after ten days of practice for the control during the end period, with both groups equal on the six month retest. Improvement was attributed to maturation of neural and other mechanisms and the acquisition of special and subtle methods of working.

Goodenough and Brian (281) reported a study in motor learning using a ring toss game with twenty children four years old. Three groups of children were given twenty trials per day for fifty days, excepting week-ends and absences. Ten children performed with no instruction as to the manner of throwing, six had their errors pointed out to them, and four were required to use one method. Some of the results obtained were as follows: The reliability of a score on a single day's performance was .50; practically no relationship was found between the initial status and gain; a correlation of —.349 was found between the total score and the I. Q.; boys exceeded the girls in mean total score; improvement was found in the course of a day's practice period; children tended to overthrow after a success; learning curves showed large individual differences with relatively small increments of improvement; and the group that was directly trained gained the most.

In the study by Hilgard (289) two groups of ten children each, aged twenty-four to thirty-six months and in attendance at the Merrill-Palmer nursery school, were equated for chronological age, mental age, sex, and approximate initial abilities in three skills: buttoning, cutting with scissors, and climbing. The initial differences between control group and practice group were unreliable on all the tests. After twelve weeks of practice the practice group exceeded the performance of the control group on all tests, but one week of practice by the control group was sufficient to bring the scores of the control and practice group to similar levels. The rapid relative gains of the control group are interpreted to mean that factors other than specific training contribute to the development of these three skills, factors which may be partly accounted for by maturation and partly by general practice in related skill. This is in accord with the findings of Gesell and Thompson reported in the section on infant mental development.

CHAPTER IV

Relationships in Physical and Mental Development

INVESTIGATIONS of physical-mental relationships have been concerned for the most part with anthropometric data, records of illness or physical defect, and ratings of nutritional status considered in relation to scholastic and intellectual measurements. The principal literature on these topics has appeared during the past decade and a half. A number of studies, however, which are at least of historical importance, date some ten or twenty years earlier. The present review does not attempt to include studies of the relationship of mental to motor development, and touches only incidentally the important field of recent research on biochemical factors in behavior. For a more comprehensive review, covering the period to 1930, the reader should consult the volume by Paterson (399).

Comparison of Group Averages

Apparently the first statistical investigation of mental ability in relation to physical size was made by Porter (406) in 1892. St. Louis children in upper grades were found to be heavier than children of the same age in lower grades. Among seven-year-olds, for example, the average weight in pounds was 45.6 in the kindergarten, 48.5 in the first grade, and 52.0 in the second grade. Similar results pertaining to height as well as to weight have been obtained by other American investigators, such as Christopher (348); DeBusk (356); Pyle (408), who used the criterion of age grade location; Arnold (342), who reported on thirty thousand Australian children, and Paull (400), who reported on fifteen thousand German children. The agreement of the findings in these investigations should not lead us to overvalue the authors' conclusions. The use of grade location as a measure of intelligence is seriously to be questioned in connection with studies of the relationship of intelligence to physical size, for among children of similar intelligence the taller and heavier may be favored by earlier entrance to school and by more regular promotions.

Teachers' ratings of intelligence were substituted for grade location in three studies of physical-mental relationships made prior to 1900. These investigations by Gilbert (368) in New Haven, West (429) in Toronto, and MacDonald (388) in Washington, D. C., yielded widely differing results. Gilbert reported no relation between mental ability ratings and height and weight. West reported a negative relationship: "It is safe to say that precocity bears an inverse ratio to bodily development." MacDonald obtained findings which he interpreted as indicating that bright children are taller and heavier than dull children, although his curves actually suggest no consistent difference except between the ages of fifteen and eighteen. It

is apparent that the unreliability of single ratings by teachers makes it difficult to reach safe conclusions by this method.

The first comprehensive study of physical-mental relationships among the feeble-minded was that of Goddard (369) in 1912 based on the heights and weights of over 11,000 children classified as idiots, imbeciles, and morons. Idiots were at all ages consistently shorter and lighter than the others. Beyond the age of fourteen there was a fairly clear differentiation in both height and weight among imbeciles, morons, and normals. Mead (391) obtained similar results, as did also Simon (420) in an earlier study in France, and more recently Rosenblüth (412) in Germany. That the differences may be due in part to selection is suggested by Rosenblüth who found that the physical inferiority of the feeble-minded was less marked among feeble-minded outside of institutions. Charles (347), in a study of delinquent boys of subnormal intelligence, found that they were normally developed in physical size and strength. In comparisons of normal with feeble-minded children, it would be preferable, of course, to treat separately cases of secondary amentia such as feeble-mindedness associated with central nervous system lesions or glandular dysfunction.

In the studies discussed above, the classification of mental ability was not based on objective mental tests. In 1928 Dayton (354) reported on the Stanford-Binet I. Q.'s of over thirty-five hundred Massachusetts children who had been found to be significantly retarded in school progress. For those who were overaverage in height (more than one inch above the norm) the mean I. Q. was 68.5; for those average in height the mean I. Q. was 66.3; and for those under average, 61.5. Similar results have also been demonstrated by Wheeler (432) for a variety of other anthropometric measurements in a study comparing 273 institutional feeble-minded children with a normal control group. This study deserves particular attention because of the control procedures and because of the use of cumulative anthropometric and intelligence test measures over a six-year period. Another control study is that of Hollingworth and Taylor (374) who compared three groups of children, ages nine to eleven. With age, sex, and race matched, groups of forty-five children each were chosen to represent widely different I. Q. zones: below 65, between 90 and 110, and above 135. The median heights were 49.6, 51.2, and 52.9 inches respectively. A similar trend was found with regard to weight.

The most recent extensive investigation comparing the average height and weight of children at different levels of mental ability is that of Kempf and Collins (380), who, in 1929, reported on a large sample of Illinois children between the ages of eight and fourteen. The children were divided into three I. Q. groups on the basis of standard intelligence tests. At each of these ages the average height was slightly less for children under 90 I. Q. than for those at 110 I. Q. or above; this was true for each sex and for weight, chest measurements, and vital capacity as well as for height. On the basis of such findings, one is tempted to conclude with Christopher

(348) that "superior mental and physical qualifications are generally associated, and inferior mental and physical qualifications are likewise generally associated." How closely they are associated remains, however, a problem to be decided by methods other than the comparison of averages.

Correlational Studies on Physical Size

Paterson (399) computed a Pearson correlation coefficient between weight and grade location for 2,169 nine-year-old boys in Porter's data. This correlation was .06 ± .01, indicating a very different order of relationship from that which was inferred from Porter's original treatment of his material. The majority of the other studies mentioned above did not give variabilities and provided no way of estimating the overlapping of distributions. The differences in average physical size shown by bright and dull children may be of little practical significance if the distributions of physical size overlap as markedly as in the case of Porter's study. Correlational procedures on large numbers of cases were apparently first used in this connection in 1910 by Heron (371) who gave data for nearly nine thousand cases of English school children. Partial correlations (age constant) between height or weight and teachers' ratings of intelligence ranged from .03 to .10.

Similar low coefficients were reported in 1916 by Doll (357) for height in relation to school grade for public and parochial school children, the original data having been given by Woolley and Fischer (433). In a sample of 477 feeble-minded, Doll obtained considerably higher correlations (with chronological age partialed out) between mental age and standing height, sitting height, and weight. The highest coefficients were with sitting height, .41 for boys and .47 for girls. The lowest were with weight, .23 for boys and .34 for girls. For another feeble-minded group, Davenport and Minogue (352) correlated mental age with a composite physical age based on vertex height, sitting height, span, annual weight increments, dentition, and pubescence. At each chronological age from nine to thirteen the correlations ranged from .24 ± .09 to .48 ± .07. These results can hardly be regarded as representative for normal groups.

Baldwin (129) in 1922 reported a correlation of .53 between height and Stanford mental age with chronological age partialed out for forty-nine girls in an age range of eleven years. This degree of relationship has not been substantiated by other investigators. In 1923 Murdock and Sullivan (394) gave standard intelligence tests (Otis Primary, National Intelligence Tests, Terman Group Test) to approximately six hundred children of north European descent in grades one to twelve in Honolulu. Correlations of .14 ± .03 were reported between height and I. Q. and .16 ± .03 between weight and I. Q. These coefficients would undoubtedly have been slightly higher if correction had been made for the negative correlation between chronological age and I. Q. which is known to occur with both the National Intelligence Tests and the Terman Group Test as pointed out by Hsiao (59).

In a preadolescent group, the correlation was .17 ± .05 with weight and .21 ± .05 with height.

In 1925 Terman with Baldwin (102) reported correlations among gifted children at each age from ten to thirteen. In this highly selected group the correlations between height and mental age averaged .18 for boys and .15 for girls, and between weight and mental age .15 for boys and .01 for girls. The follow-up study of these children by Burks, Jensen, and Terman (9) reported no anthropometric measures, but gave data on health history. Among forty-seven Jewish children with I. Q.'s above 135, Hollingworth (191) found at ages seven to nine a height superiority approximately 5 percent over the averages of unselected New York Jewish children. This superiority was maintained in annual remeasurements over a six-year period.

Abernethy (340) found for 120 girls between six and twelve years of age a partial correlation (age constant) of .39 ± .05 between weight and Stanford mental age and .34 ± .05 between height and mental age. For older girls from thirteen to seventeen the correlations were smaller, averaging approximately .10 when computed for each age separately. If the lowering of correlation is significant and is not attributable to selection, the hypothesis may be offered that puberty tends to produce individual differences in physique uncorrelated (or slightly negatively correlated) with intelligence.

Other investigators, however, have reported similar low correlations in the lower grades. Gates (367) in a well-executed study, reported for kindergarten and fourth-grade children average coefficients of .06 between weight and Stanford-Binet mental age, and .10 between height and mental age. For 560 children in grades five to twelve, Stalnaker (423) found correlations insignificantly different from zero between I. Q. and physical measures (height, weight, trunk length, vital capacity, and chest circumference) reduced to deviation from Wood's and Dreyer's age norms. A practically zero relation was also found by Pearson and Moul (404) for 1,196 Jewish children when height and weight were correlated with intelligence ratings by teachers.

Studies of college students have been reported by Stalnaker (423), Brooks (145), and Sommerville (422) at Columbia, and Lee, Lewenz, and Pearson (384) at Cambridge. In all these the correlations were very low, tending to be positive but not significantly different from zero. Somewhat different results were obtained in a recent investigation by Westbrook and Lai (430) on Chinese students in Shanghai. Their paper, however, bears internal evidence of statistical errors.

Data for the preschool period are available from the California growth study (427), with weight and length measurements and intelligence scores (reduced to sigma deviations for age) correlated at successive points from birth to three years. All coefficients are positive but low, averaging approximately .10.

Interpretation of Results

Results from these studies are in reasonably good agreement. It would appear that the partial correlation (age constant) between intelligence and any one measure of physical size may as a rule be expected to fall between .10 and .30. As previously noted, higher degrees of relationship are occasionally reported (102, 340, 352, 357), but correlations near zero are often found. In interpreting such differences, the following points should be considered:

1. Correlations based on I. Q. (without partialing) may be lowered by factors involving scaling errors which artificially produce a diminishing I. Q. with age, as shown by Jones (377).

2. Correlations may be inflated by racial or social heterogeneity, producing the appearance of fairly close relationship when no functional correlation is present. An opposite effect may also occur at certain ages, as shown by Serota's data (417) in which Italian children were found to be accelerated in physical development and retarded in mental development with reference to age norms.

3. An aberrant correlation in the zero order coefficients, as between mental age and chronological age, may lead to spuriously high (or low) partial coefficients as shown by Paterson (399: 149).

4. Correlations with weight may be disturbed by heterogeneity as to body build or by the tendency for well-nurtured children to be underweight during periods of rapid growth in stature, as shown by Schiötz (416).

5. The correlations of mental age and chronological age and of physical size and chronological age may each vary somewhat independently according to the age range considered. Partialing out chronological age for a wide age range may yield, therefore, a partial r which is not representative of narrower age intervals.

6. The problem of the correlation of physical measurements with, for example, school achievement may be complicated by the occurrence of a compensatory drive in certain individuals resulting from the awareness of physical inferiority. The role of compensation has been investigated in quantitative terms by Adams (341), who found a negative correlation between height and achievement when mental age was held constant. On the other hand, Hollingworth and Gray (373) failed to find any relation between physical size and accomplishment quotient among gifted children. In a group of crippled children investigated in an orthopedic follow-up, Lightfoot (385) reported that the effect of compensation was not demonstrable in achievement, but was evident in their attitudes.

Certain other considerations applying to correlational methods in the attack upon this problem will be discussed at the conclusion of this chapter. It is clear, however, that for purposes of general diagnosis or prediction and for use in connection with sectioning or other problems in school administration, the correlation of physical size with intelligence is too low to be regarded as of any practical importance. This appears to be true, not only for height and weight, but also for all other physical measurements which have been investigated.

Head Measurements

Miller's statement (392) based on a study of children in Victoria and Tasmania, that head measurements are of value to supplement mental tests in measuring intelligence, is not substantiated by the results from ac-

cepted investigations in this field. See particularly Pearson (403), Pearl (402), Estabrooks (361), and the results of Kempf and Collins (380) in measuring the "head module." The data are also negative with regard to the existence of a relationship between intelligence and cephalic index. Extreme pathological deviations, as in microcephaly and hydrocephaly, are associated with mental defect, but within a very wide normal range of head size and shape no dependable correlation exists with intelligence.

Relationships with Other Mental Traits

Relatively little has been done on the relationship between height and weight and factors other than intelligence or school achievement. An approach to this has been made by Furfey (171). With an interest and attitude test designed to measure "developmental ages," he obtained correlations of .22 and .16 with weight and height respectively (chronological age partialed out). The reliability of his test (.76) was lower than for most intelligence scales. Concerning height and leadership, Bellingrath (346) reported that school leaders are taller and heavier than the average of their classmates. Such relationship is, of course, more influenced by the cultural pattern than the relationship between height and fundamental capacities.

Body Build

We may turn now to the question of the predictive value of anthropometric indices, such as the ratio of weight to height. According to one theoretical formulation, individuals with a slim, narrow body build are of a predominantly thyroid type and are more likely to develop mental superiority. In 1921 Naccarati and Lewy-Guinzburg (396) stimulated investigation in this field by stating: "Intelligence cannot be correlated with a simple physical trait such as height, weight, cephalic index, etc. A basis for correlation must be found in a compound physical trait which is made up of several anthropometric traits." With a weight-height ratio he obtained an r of $.23 \pm .04$ with the Thorndike Intelligence Examination given 221 Columbia students.

Results by other investigators have yielded lower coefficients and more conservative conclusions. In the California growth study (427) correlations were computed between intelligence (sigma scores) and W/H^2, which with this material was shown to be the most adequate single index of body build. The correlations at three, six, twelve, twenty-four, and thirty-six months indicated no significant relationships. Among 191 children from ages two to thirteen, Johnson (376) obtained a coefficient of $.04 \pm .05$ (chronological age held constant) between Stanford-Binet mental age and weight-height index. Coefficients obtained by Stalnaker (423) for high-school pupils and by Sommerville (422), Heidbreder (370), and Garrett and Kellogg (366) for college students were all close to zero.

To test the possibility that the ratio of limb length to trunk volume might give a better indication of intelligence than the relation of height to weight, Sheldon (419) correlated this index with intelligence for 434 freshman men at the University of Chicago. The coefficient was reliably greater than zero, but too low to be of any value for purposes of prediction (.14 ± .03). Body form like body size can now be neglected as a general developmental associate of intelligence. An additional finding reported by Sheldon was a negative correlation between morphological index and ratings on sociability (−.22 and on leadership −.14), suggesting that the slim, asthenic individual is slightly less likely to be a leader. Again the correlation is too small to be of predictive value. The psychiatric literature concerning the relationship of body build to emotional and personality traits is so extensive as to require a separate review. Kretschmer's theories (383), which have stimulated much of the work in this field, have been largely concerned with the relationship of psychotic reaction types to alleged types of physique; no substantial accumulation of data has yet been made on normal samples.

Anatomical and Physiological Age

In addition to height and weight, numerous other indicators have been proposed for measuring an individual's level of physical development with the hope that such measures would be of value in connection with the interpretation of mental status and the prediction of mental growth. These expectations have not thus far been realized, and there exists at this time considerable doubt as to the possibility of finding any single physical measure, or any composite of measures, which will correlate in an important degree with mental ability when mass data are used.

Early research on growth indicators is marked by the papers of Pryor (407) and Rotch (413) on the skeletal development of the wrist and hand; of Beik (345), Bean (344), and Matiegka (390) on dentition; and of Crampton (351) on pubescence. It was proposed that carpal ossification was better than height or weight as a measure of anatomical development, because body type affects the interpretation of height or weight data, while the type of hand has relatively little effect upon ossification ratio (360). In 1922 Severson (418) stated that the conditions of the carpal bones, together with the styloid process and the epiphysial union, give us a better insight into the physical and mental development of the child than the chronological age. This is proved by the close correlations. For one hundred ten-year-old children in Minneapolis, his correlation between anatomic age and I. Q. was, however, only .31 ± .06.

Between 1922 and 1925 four important studies were conducted on the relationships of "carpal age" or "ossification ratio" to I. Q. or to mental age with chronological age held constant. On samples of school children totaling over 750 cases, four investigations by Lowell and Woodrow (387),

Freeman and Carter (170), Gates (367), and Abernethy (340) agreed in finding positive but extremely low relationships between anatomical and mental development. Gates also measured other physical traits including height, weight, chest girth, and vital capacity. When all the physical measurements were combined, their multiple correlation with mental age was only .21; and when these physical measurements were added to mental age, they increased the prediction of educational achievement only from .60 to .63. In a study by Cook (349) on six groups of school children ranging in size from 72 to 124, the conclusion was offered: "If anatomical development has any significance whatsoever for school administration, it does not appear in our data, nor does it appear in any other studies of consequence which have been reported."

It has been thought possible that anatomical and mental growth are more intimately related in the preschool years than later when diverse environmental factors are increasingly operative. This hypothesis, however, is not supported in results from the California growth study (427). At twelve, twenty-four, and thirty-six months no significant relationships were found between mental sigma scores and skeletal development as measured by the ossification of the epiphysis of the upper tibia. At twenty-four and thirty-six months, the coefficients dropped to slightly negative values. A further point of interest was the markedly faster rate of skeletal development among girls in the early preschool period. This was not paralleled by a difference in mental development between the two sexes. In the light of this and of the foregoing studies there appears to be little justification, at any age level, for attempting elaborate composites of X-ray measures in the hope of obtaining significant correlations with intelligence.

Dentition

The eruption of the permanent teeth is known to involve wide individual differences in children. Are these differences in dentition related to differences in rate of mental growth? Lowell and Woodrow (387) and Abernethy (340) obtained no better correlations between mental age and dentition than between mental age and skeletal development. In the Harvard growth study, Cattell (271) reported a correlation of only .11 (chronological age constant) between dentition and mental age for five hundred boys between the ages of five years, six months, and eleven years, six months. For over two hundred girls, correlations in single-year groups ranged from .05 to .12. Growth curves based on averages reveal a very slight tendency for the dull-normal and feeble-minded to lag behind the unselected and superior. The only investigation reporting more significant relationships is that of Perkins (405), which has been criticized by Paterson as involving apparent errors in statistical treatment. Jonoff (378) has reported for a small sample of Russian children that early permanent teeth are characteristic for intellectual precocity. The group accelerated in dentition was also found to have a superior parentage as to social and edu-

cational status and as to the incidence of tuberculosis and alcoholism. The results are not in a statistical form to permit an estimation of their significance.

Pubescence

Pubescence as an indicator of mental maturing has fared no better than other measures in spite of the early predictions of Crampton (351). Studies of the age of pubescence in relation to mental development during adolescence (340), postadolescent intelligence (249), and scholastic performance (363, 381) have indicated no significant correspondence. There appears to be a slight tendency for very precocious sexual maturity to be associated with mental retardation. In this connection, see the summary by Stone and Doe-Kulmann (425) of the literature on puberty praecox. There is also some indication, as shown by Abernethy (340), that extremely late pubescence may be associated with scholastic difficulty, due to failure of normal social adjustment rather than to intellectual retardation. With regard to the significance of age of puberty for later mental development, Viteles (249) concludes: "If there is a spurt in development with the onset of puberty, those who mature late profit about as much by it as those who mature early, and the effect of such a spurt is not seen in adult life."

Physical Condition

If weight is regarded as a measure of nutritional status, the low correlations between weight and I. Q. would suggest that within fairly wide nutritional limits intelligence develops independently of this factor. A number of studies are available in which mental ability is considered not merely with reference to weight, but also to a variety of physical defects or handicaps. One of the earliest of these is that of Cornell (350) in 1908. He divided 705 Philadelphia school children into two groups on the basis of physical record with the result that the two groups showed a scholarship performance of 74.6 and 71.0, the significance of which cannot be determined on the basis of the data given.

In the following year Ayres (343) reported for over three thousand children an average of 1.07 defects for the "bright," 1.3 for normal, and 1.65 for dull children. The dull children showed consistently larger percentages of enlarged glands, defective breathing, defective teeth, enlarged tonsils and adenoids, but not more defective vision. Sandwick (414), comparing the highest and lowest 10 percent in intelligence tests of approximately four hundred children, reported an average of .7 defects for the bright group against 3.4 for the dull group. In an extensive study in two Illinois counties, Kempf and Collins (380) found in one county near Chicago a consistently greater incidence of physical defects among children of lower I. Q. (below 90). This was particularly marked for defective hear-

ing, but was found also for decayed teeth, diseased tonsils, enlarged thyroid, defective vision, heart defects, and malocclusion. Tonsillectomy and mastoidectomy had occurred oftener among children of higher I. Q. (above 110). Rickets and nervous symptoms such as nailbiting were unrelated to intelligence. In the second county studied, in the southern part of the state, these findings were not repeated, suggesting the dependence of relationships upon population composition. The relationship of physical defect and I. Q. is one which cannot be directly interpreted in terms of direction of causation. Either variable may conceivably influence the other, and both may be independently influenced by hereditary and environmental factors associated with race and social status.

If we turn to correlational evidence, we find that here, as in the case of investigations of physical size, correlations present a somewhat different picture as to the closeness of relationship. Heron (371) found partial coefficients of below .10 between "nutrition status" and teachers' ratings of intelligence. Equally low relationship was found with the condition of teeth, tonsils and adenoids, and cervical glands, the highest being .17 with hearing in the case of girls. Such differences are probably related to differences in the reliability of measurement. Franzen (365) has shown that in the rating of nutritional condition the average correlation between two physicians was only of the order of .6.

Results similar to Heron's were obtained by Pearson and Moul (404) who concluded:

> To sum up, we have not succeeded in finding any relation of real prognostic value between intelligence and such pathological characters as we have been able to measure. . . . The sole factor which appears to have a small but real influence on intelligence is that of defective teeth in boys . . . (unless the reader is so perverse as to suggest that the unintelligent by neglecting their teeth encourage dental caries).

The recent nation-wide study of the American Child Health Association, reported by Franzen (365), is not directly comparable in this connection because correlations were computed between averages for fifth and sixth grades in sixty-eight schools rather than between individuals. In these terms, however, the correlation was .63 between intelligence and "proportion of caries corrected." The obvious interpretation is that factors associated with intelligence are also associated with provision for dental hygiene. Mallory (389) conducted an extensive study of 515 Tennessee school children, but his results are somewhat difficult to interpret owing to absence of data concerning age, sex, and social status. In general, correlations between physical defects and intelligence or physical defects and school achievement were positive but low. He considered that the most important physical defects producing mental retardation are nasal obstruction, defective teeth, hearing, tonsils, and vision, named in the order of importance.

Dayton's recent report (355) on more than fourteen thousand retarded

school children in Massachusetts is based on a defect score from a physical examination and a mental age from two parts of the Fernald ten point scale. The correlation between I. Q. and defects was $-.29 \pm .01$ for boys and $-25 \pm .01$ for girls. In such a study, based on cases marked as retarded, the question always arises as to the possible effects of selection. Here it would appear that selection would probably make for a positive rather than a negative correlation, higher I. Q.'s being more likely to be marked for school retardation when associated with obvious physical defects. Dayton's results are apparently in conformity with those of Doll (357) and of Davenport and Minogue (352), previously mentioned, which suggested that among feeble-minded a somewhat closer relation exists between physical and mental development than holds true in a normal sample. This may be due to the presence of associated mental and physical defects from birth injuries and other environmental causes.

Several investigations of a quasi-experimental nature have been made in which the intelligence or achievement of children has been compared before and after a period of treatment. Rogers (411) tested fifty-six children with diseased tonsils, and repeated the test six months later after twenty-eight of the subjects had been operated on. No differences in mental development were shown between the experimental and the control group. A similar study by Lowe (386), with a year's interval after operation, yielded similarly negative results. Fox (364) obtained I. Q.'s before and after glandular therapy on twenty-two cases of glandular dysfunction. Retests after a period varying from four to twenty-four months showed no intellectual gains attributable to therapy. Quantitative evidence as to the effects of thyroid treatment in cases of marked subthyroidism is not yet available in satisfactory statistical form; although it is a common clinical tradition that thyroid administration to cretins, particularly in early infancy, produces a marked effect upon mentality.

Paulsen (401) studied the effect of a month's remedial treatment for intestinal toxemia in thirty young women compared with thirty normal controls. The net average gain of the experimental group was slight on a series of mental tests (opposites, cancellation, etc.), but more marked on motor tests. This is in agreement with the findings of Nicholls (397), who reported malnourished children to be inferior to controls in motor and muscular functions but not in any of the intellectual functions which were tested. Dowd (359) found that undernourished children in a nutrition class failed to gain in intelligence as compared with a control, but that the more intelligent children gained more rapidly in nutrition. Similar relationships are also suggested in the work of Hunt, Johnson, and Lincoln (375).

In a group of approximately four hundred Wisconsin school children, Westenberger (431) identified the poorest 10 percent with respect to physical defects, and medical and surgical treatment was provided. In a nine-month period, no effect upon mental development was noted as a result of this remedial care. He concluded that "the influence of defects

upon academic performance and intelligence has been somewhat exaggerated in the past." The effect of health education was investigated by Hoefer and Hardy (372), who carried out a three-year program of instruction with 343 children, classified into three groups on the basis of physical condition. No reliable differences were found in the mental development of these groups. Similar results were reported by Kohnky (382) concerning the effects of instruction for seven months in dental hygiene, together with dental treatment.

With reference to specific disease conditions, several studies have been made concerning the effect of hookworm on school progress or on mental test scores by Stiles (424), Waite and Neilson (428), Kelley (379), and Myers (395). These studies agree in suggesting that mental retardation is associated with hookworm. The degree of association is very tentatively suggested by a correlation of $.30 \pm .06$ between Otis I. Q. and hookworm frequency as computed by Paterson (399) for the data of Smillie and Spencer (421). An experimental study was reported by Strong (426) on the comparison of a group of children infected by hookworm and a group of normal controls. On a series of mental tests, the percentage of infected children equaling or surpassing the median of the normals was 36 percent before treatment and 26 percent after cure! His cases were too few in number and too many complicating social and economic variables were present to justify the statement that "hookworm disease interferes very radically with mental development." The most recent study in this field is that of Schell (415) in California comparing sibling pairs in which one member of each pair was positive and the other negative with reference to the presence of pathogenic intestinal protozoa. The sibling correlation was $.57 \pm .048$, showing no evidence of lowering by differential environmental factors. There were no reliable differences between the two groups in the average I. Q. or in measures of personality traits.

Another study employing the method of sibling comparison was that of Fernald and Arlitt (362), who compared admissions to a school for crippled children with a control group of brothers and sisters. There was no reliable I. Q. difference between the two groups, and the sibling correlation (.52) was similar to that expected for ordinary sibling pairs. Dawson and Conn (353) compared twenty-three encephalitic cases with normal siblings. An I. Q. difference of 9.4 points was found in favor of the normal children. Although the cases are too few for drawing conclusions, there is no doubt that retarded mental development may be produced by encephalitis and other diseases or injuries directly affecting the central nervous system. Doll (358) reported that 10 percent of institutionalized cases of mental defect are attributable to intracranial hemorrhage at birth, with correlated motor and mental impairment and with subsequent tendencies to disturbance in personality. Two studies have been made of thyroid enlargement in relation to intelligence by Olesen and Fernald (398) and in relation to scholarship by Stocks, Stocks and Karn (234). No significant relationships were found.

Conclusions and Limitations of the Data

A summarizing statement to cover the results reported above would be: In general, desirable physical characteristics are positively correlated with desirable mental characteristics. Mohr (393) reported that this is true even of beauty or physical attractiveness in relation to intelligence. But the correlations are too low to be of value in prediction or as an aid in the practical problem of classification. It must be remembered, however, that nearly all the data presented deal with correlations in groups. Compatible with low correlations in groups, significant relationships may occur in individuals. The following possibilities may be considered:

1. For certain pairs of traits, a marked functional relationship may occur in certain individuals, but these individuals may be so few (clinical deviates) as to have little effect upon the mass data.
2. For certain pairs of traits, individuals may be found who exhibit a (functional) negative correlation running counter to the prevailing positive relationship. This will tend to reduce coefficients in the mass data, as illustrated in the studies reported above on the effects of compensation.
3. Two traits which are correlated in a certain low degree may at a certain age be markedly affected by a third factor. This factor may produce a greatly enhanced correlation in growth rates of the two traits without markedly affecting the correlation of amounts.
4. Relationships between physical and mental traits may involve functionally significant patterns of physical characteristics which differ qualitatively in different individuals. If such is the case, no single pattern when correlated with mental traits can be expected to yield a high correlation in the mass data.

Evidently, in the past we have focused attention too largely upon obvious end products of physical growth, such as height and weight and body build, rather than upon fundamental metabolic processes. Richter's study (410) of endocrinological factors in drives to activity in rats gave excellent experimental evidence of the reality of such physical relationships. Richter's methods cannot be duplicated with children, and it is, therefore, difficult to advance the knowledge of these relationships beyond the realm of clinical observation. Our next stage of research must place its emphasis not in mass correlations but in individual growth studies, pursued intensively and with particular attention to concomitant changes in curves which express physiological functions, physical growth, and mental development.

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Chapter II. Mental and Physical Development in Adolescence

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Chapter III. Physical Growth from Birth to Puberty

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Chapter IV. Relationships in Physical and Mental Development

(See also nos. 9, 59, 102, 129, 145, 170, 171, 191, 234, 249, 271)

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